Evaluation of the Customary Fisheries Management of Shellfish in the Canterbury Region

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Abstract

During the last twenty years there has been a growing recognition of the need to protect shellfish populations all over the world. In New Zealand, customary management tools such as rehab (temporary closures) and mātaitai reserves provide an important management strategy, allowing shellfish populations to be managed and protected in coastal waters. This thesis examined the cultural management of shellfish in three Māori reserves in the Canterbury region, at Rāpaki, Port Levy and Kaikōura. The study measured the population characteristics of three key shellfish species that are important to Māori within the reserves and compared them with similar non-reserve sites. The shellfish populations were assessed using both scientific methods and cultural evaluations using traditional ecological knowledge (TEK). The scientific methods involved assessments of the abundance; size structure and condition index of pipis (*Paphies australis*), cockles (*Austrovenus stutchburyi)* and cats eyes (*Turbo smaragdus*). Semi-structured interviews were used to gather indigenous knowledge from kaumatua and kaitiaki on the abundance of shellfish and the state of their customary fisheries. The findings from the scientific research indicated that the customary reserves had higher shellfish abundance, larger individuals and higher abundance of harvestable size shellfish. The result of the cultural assessments suggested that there are enough shellfish in the three reserves to satisfy the customary needs of the communities. The kaitiaki acknowledged that the abundance and sizes of shellfish had been greater and larger in the past compared to the present. They have observed an increase in both size and abundance of shellfish since the customary reserves have been put in place. This study showed that scientific monitoring can provide important information about the structure and distribution of shellfish and that this is critical for sustainable management. The research findings indicated that scientific monitoring and TEK information can compliment each other for improved customary fishery management. The thesis research concluded that differences in shellfish populations between the reserves and non-reserve sites may be due, not only to the customary management, but a variety of complex factors that will require further monitoring. This research, however, provided baseline data about shellfish populations which can be used to monitor future changes. From a cultural perspective the customary management is conserving shellfish populations and therefore is successful at fulfilling the customary needs of the three Māori communities.

Acknowledgments

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Finally I dedicate this thesis to my family, Doris, Makario and Peter for their support and for helping me with the counting and measuring of shellfish, especially during the cold winter. Special thanks to Doris my wife for her support and understanding during my years of study.

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Customary Fisheries Management of Shellfish in the Canterbury Region

1.1 Introduction

Fisheries are economically, socially and culturally important to the future development of many countries of the world. There is a growing interest in many of these countries, among scientists, fishery managers, economists, marine biologists and conservation groups, about the role of traditional customary fishing rights in the management of local community fisheries (Cinner and Aswani, 2007). These different interest groups have promoted the use of the customary fishing rights as a foundation for the sustainable use of fisheries resources, because of their dissatisfaction with modern fishery management systems (e.g. Rosenberg et al, 2006). Traditional rights based management systems, practiced for centuries by coastal communities, have also been recommended by many authors (e.g. Johannes, 1978; Pollnac, 1984; Chapman, 1985; Nietschmann, 1985; Ruddle, 1988; Cordell, 1989) to prevent overfishing and distribute fisheries resources.

Traditional customary fishing rights of coastal communities have been acknowledged in various parts the world, especially in the Asia- Pacific region (Ruddle and Johannes, 1990), it is also practiced in the Caribbean, South America, Africa, Middle East, North America, Australia, New Zealand several countries in Europe and Japan, (Ruddle, 1994). In these countries the customary fishing rights have been very successful in controlling free access to fisheries which has been advocated to be the main cause of depleted fisheries all around the world. The Padu system is an example of customary marine tenure or fishing rights in South Asia that has continued to exist in the face of swift expansion and transformation in the fisheries in the region. The system has been used by the local people for many generations and has played an important role in sustainable fisheries because it has (i) successfully restricted fishing access to members, (ii) efficiently controlled dispute between communities (iii) been able to restrict fishing pressure (Coulthard, 2011). In Chile, the traditional customary property rights called Parcela system has been in existence for almost a century and has been valuable in distributing fisheries resources fairly to members as well as being durable. In Pacific Island countries customary management practices have been legally recognised by national governments and have become very important tools in the modern fisheries management (Johannes, 2002).

Failures of community customary fisheries management have also been documented in various part of the world. History of community fisheries management suggests that some of the activities associated with food gathering were destructive and had resulted in degradation of ecosystem and loss of biodiversity. Early Māori settler's hunted food with very little thought for the protection of the resource (Annderson, 2003) and after a few hundred years had overexploited the moa species (Bess, 2010) and shellfish species (Flannery, 1995). The depleted food resources prompt Māori to develop customary management strategies to protect land and sea resources (Boast, 2005). According to (Johannes, 2002) cultures that have conservation principles have certainly experienced depleting their natural resources at some time in their history and learned that the resources have limits. If a community does not go beyond the sustainable boundaries of its natural resources then it should not be expected to acquire a conservation attitude (Cinner and Aswani, 2007).

Traditional management practices in most instances have stemmed from finely tuned knowledge of the biology of targeted species and a natural conservation principle (Johannes, 1981, 2002). Although there is swelling evidence that community rights management system has the potential to sustain fishery resources and be effectively modified to compliment modern fishery management, there are still many scientists and economist that continue to have doubts about its merit (Aswani, 2005). This thesis research is going to investigate the conservation value of Māori Customary Management in New Zealand and its ability to conserve fisheries resources such as shellfish.

1.2 General Approaches to Fisheries Management System

The history of fisheries management is filled with many examples of failures to sustain yields of fish harvests, conserve the marine environment, protect coastal communities, or the profitability of the fishing industry (Cochrane, 1999). There is no specific solution to the crisis of declining fisheries because there is no specific remedy that suits all situations. Management of fisheries is a complex economic, ecological, social systems ((Brady and Waldo, 2009). A management approach is often well suited to solve a particular problem in a fishery, but not to solve them all.

Fisheries management can be generally described by three approaches: (1) centralised top-down system which promotes the use regulation of gear, fishing time and location and catch; (2) the property rights-based management system (QMS) based on Individual Transferable

Quota (ITQ) and (3) Community based system which advocates a bottom up approach. The increase interest in the use of community–based fishery management has been a result of (i) the failure of centralised and modern fishery rights (ITQ) management to sustain fishery resources (ii) the worldwide movement of transferring resource management to a community level and (iii) the acknowledgment of the existence of rights to utilise and manage resources competently (Charles, 2004).

1.3 Community Management System: Customary Fishing Rights

Customary management practices have been described by (Cinner and Aswani, 2007) as "local practices that are designed to regulate the use, access and transfer of resources". This management approach has been grounded in the observation, knowledge and experiences of local people with their local environment for many thousands of years (Berkes and Folke, 1998). In fisheries, this customary management practices are referred to as Community or Customary Fishing Rights (CFR) or customary marine tenure (CMT) as it is known in Pacific Island Countries. In this research Customary Fisheries will be used to mean Community Fishing Rights and customary marine tenure. The basic concept of the fishing rights is that it is a right held by a group of people or community and not individuals who have formal powers and potential to implement an effective fisheries management system. In many locations throughout the world, these community rights to fishing territories have been accepted by maritime cultures for centuries, but hardly get mentioned in the economics of fisheries literature, which has alternatively concentrated on individual fishing rights (Copes and Charles, 2004).

The existence of customary fisheries in many countries of the world has been researched and acknowledged especially in Asia and Pacific counties (Ruddle, 1994). The advantages of customary fisheries are that rights holders themselves in this case traditional authorities carry out the key management roles and not the central government. Communities through their traditional authorities are able to (i) enforce rules effectively through social sanctions in various forms (ii) set conflict resolution procedure (iii) define fishery boundaries and (iv) define eligible users (Berkes, 1989; Cinner, et al. 2006). Community members respect and abide by the rules they help design and able to supervise each other's behaviour and identify those who violate management rules (William, 2000). All tradition customary fisheries depend considerably on community values, behavioural custom and social arrangements for it to function cohesively. Community members have a deep sense of trust and belief in each other resulting in a higher degree of agreement and lower level monitoring and enforcement (Baland and Platteau, 1996). It is fundamentally because of these above reasons that there is an increased attention on the operation of customary fishery institutions, the method in which they regulate the right to use fisheries and their capacity to enhance the success of attaining sustainable fisheries (Cinner, 2005; Jentoft, 2004; McCayet al, 1998). Many authors have declared that CFR management practices can improve the efficiency of the fisheries due to its ability to enforce management rules effectively at a less cost compared to the central government (e.g. Johannes, 1978, 1981; Hviding, 1989b; Akimichi, 1984; Chapman, 1985; Dahl,1989; Foster and Poggie, 1993; Hyndman, 1993; Begossi, 1995; Ruddle, 1998; Berkes, 1999).

The 1992 United Nations Conference on the Environment and Development recognised the importance of tradition coastal marine management systems internationally. Chapter 17 of the Rio Declaration, section17.81(c) propose the development of ‘systems for the acquisition and recording of traditional knowledge concerning marine living resources and environment.” Section 17.92(c) encourages the promotion of “study, scientific assessment and use of appropriate traditional systems.” Section 17.93 (c) encourages the equitable participation of local communities and finally section 17.94 (b) proposes the provision of “support to local fishing communities in particular those that rely on fishing for subsistence, indigenous people and women, including as appropriate, the technical and financial assistance to organise, maintain, exchange and improve traditional knowledge of marine living resources and upgrade knowledge on marine ecosystems” (United Nations, 1992). This international recognition has created a universal awareness of the need to learn, evaluate, and utilise traditional management practices where ever it existed in the world (Veitayaki, 1998).

1.4 History of New Zealand Fisheries Management

1.4.1 Centralised Management

The arrival of Europeans signified the beginning of the transformations of the New Zealand fisheries from a community subsistence fishing to a commercially exploited resource. Māori fishing rights governed by traditions authorities were gradually weakened and ultimately substituted by a centralized management system ensuing in a fishery managed disjointly for multiple stakeholders (e.g., customary, commercial, and recreational fishing (Whyte, et al, 2008). Nightingale (1992) states with the arrival of Europeans in New Zealand, the government claimed possession of New Zealand fisheries with a narrow and vague appreciation given to Māori rights. The fisheries were perceived as a public property to which everybody had free access until the fisheries becomes overfished (Nightingale, 1992).

Centralised management through government regulation of commercial fishing started in 1877 when the Marine Department established the Fish Protection Act of 1877. Centralised government controls to manage fisheries was formalised in the Fisheries Act of 1908, which operated until 1983 (Figure 1.1). The Act specifically introduces government input controls which include limited entry licensing, closed areas and season, controls on minimum fish size as means to control overfishing (Sissenwine and Mace, 1992). It became clear during the 1980s that the centralised management system was not working; it had promoted over-capitalisation and over harvesting (Ackroyd, et al, 1990; Ministry of Fisheries, 1996). The fishing industry was not sustainable, and there were growing anxiety about the poor state of most inshore fisheries (Clark, 1985; Nightingale, 1992). Suspension of new permits did little to control the increasing fishing effort (Clark and Major, 1988). It had become very obvious that the centralised fisheries management techniques were not effective in achieving either ecological or social sustainability. New institutions enabling fishing communities to deal with the present pressures were therefore needed

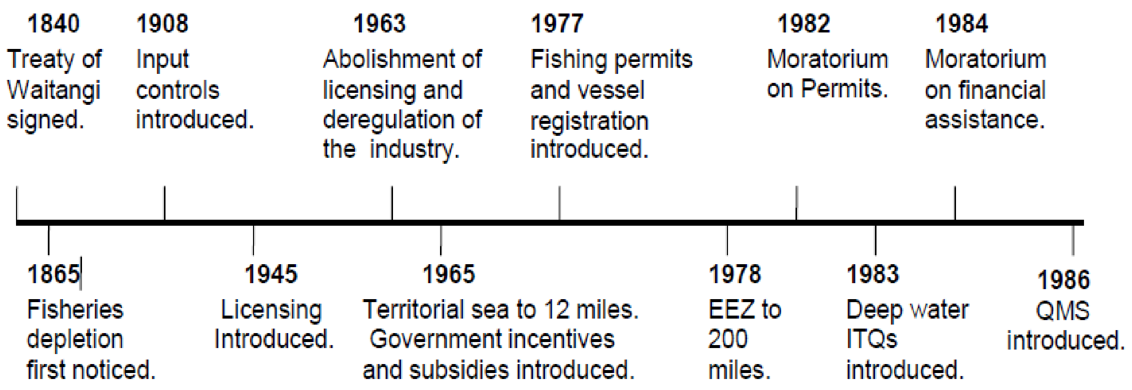


Figure 1.1: Key dates in the development of New Zealand Fisheries Management. Source: (Straker, et al. 2002)

1.4.2 Individual Transferable Quota (ITQ)

In 1986, the government decided to adopt the Quota Management System, with transferable property rights, known as Individual Transferable Quota (ITQ) to manage New Zealand fisheries (Figure 1.1). New Zealand became one of the first nations to adopt ITQ. The ITQ was adopted with two general objectives: conservation, to use fisheries resources in a sustainable way; and allocation, to encourage economic efficiency and profitability to the nation (Crothers, 1988).

The assessment of the use of ITQ as a fishery management strategy in New Zealand is extensive and well documented (*i.e.* Annals 1996; Batstone and Sharp 1999, Yandle 2003; Newell and Sanchirico 2005). There are those who support ITQ and have positive comments example (Connor, 2004; Sen, 1999; Sinner et al, 2004; Sinner and Fenemor, 2005) and there are critics of the system (Gibbs, 2008; Harte and Bess, 2000; Batstone and Sharp 1999, Stewart. et al. 2006).

One of the important advantages of ITQ management that is advocated by researchers is that it offers a competent method for the conservation of stock as well as sustainable fishing because it places a ceiling on the Total Allowable Catch (TAC) (Clark et al, 1988; Crothers, 1988; Clark, 1993). Is stock conservation and sustainable fishing an outcome of ITQ? This is an important question to find answers to in order to judge the effectiveness of ITQ. Yandle (2001) believes it is a question that many including fisheries scientists would be reluctant to provide an exact answer. When determining whether ITQ is a sustainable management system one of the fundamental subject that needs to be assessed is the quality of data available to accurately determine TAC. The TAC of a species for a given year can only be set after the Maximum Sustainable Yield (MSY) is established. There is no straight forward method available to fisheries researcher to calculate MSY, instead they must determine it by ascertaining how a fishery reacts to fishing stress. Data on fish stock behaviour to stress are inadequate, and models of population reactions are difficult, so there is a lot of doubt present in how TAC is set (Straker, Kerr, and Hendy, 2002). According to Yandle (2001) the critical data that are required to manage an ITQ approach that will result in a sustainable fishery is absent, even though fisheries science in New Zealand is exceptionally of high class.

The success of modern fisheries management is measured basically by its ability to sustainably utilise fisheries resources. The failure of the centralised management system and continuous debate about the sustainability of ITQ system has generated an interest in how community rights can be used to manage inshore fisheries in countries like New Zealand where it had traditionally been used by its indigenous people. Customary marine management of coastal marine resources has been the subject of lively academic research within the Pacific region and elsewhere in the World. In the South Pacific region numerous studies on customary marine resource management have been conducted by a number of researchers (e.g. Hviding, 1989, 1996; Carrier, 1987; Ruddle, 1996, 1998; Hickey, 1998, 2006; Asafu-Adaye, 2000;, Townsley, et al. 2001; Lam, 1998; Johannes, 2002; Cinner, 2006). In New Zealand little has been researched about the Māori customary fisheries management.

1.4.3 Māori Customary Fishing Rights

Indigenous coastal communities usually have their own internal regulatory system for management of their fishing activities. Māori as indigenous people of New Zealand held customary fishing rights under British common law (Hooper and Lynch, 2000). Māori traditional customary fishing rights management system has a very interesting history. It is unique compared to other countries in Asia and the Pacific, in the way it was weakened by colonial administrators, and then recently revived through the court system. Fishery legislation from 1840 to 1983 did not acknowledge the right of Māori to own and be involved in the management of fisheries (Bess and Rallapudi, 2007). For over one hundred years the Māori community was deprived the right to practice their indigenous knowledge and community customary management skills in managing their local fishing grounds (Webster, 2002).

The introduction of the Fishery Amendment Act 1986, which established ITQ as a management system was strongly objected by Iwi (Māori tribe) who view ITQ as removing their rights to be involved in fisheries management and utilising their traditional conservation practices and their extensive knowledge of the sea (Waitangi Tribunal, 1988). Māori alleged to the high court and the Waitangi Tribunal that ITQ violated the Treaty when it granted fishing rights to commercial fishers to fish in marine waters that they customary owned (Bess, 2001). The high court ruled that Māori still had their fishing rights in their customary fisheries. According to (Webster, 2002) the ruling demonstrated that Māori had treaty rights as well as rights under the aboriginal law title and British common law.

As a result of the high court ruling, Māori and the government negotiated a settlement, which resulted in the establishment of fishing regulations that recognise the Māori fishing rights. The Māori Fisheries Act 1989 have requirements for the government to acknowledge the tino rangatiratanga (undisputed Māori rights to their resources, land, forests and fisheries) by improving Māori engagement in fisheries management and the recognition of the establishment of taiāpure (Bess, 2001). The 1992 Act outlines the procedures for the design of Community Fisheries Management tools such as mātaitai reserve, the appointment of kaitiaki and the taiāpure provisions introduced in 1989. The Fisheries Act of 1996 contains regulations that describe how customary fishing could be exercised and the rights and duties of tangata whenua in managing their customary fisheries. The 1996 Act not only endorse the obligations in the 1992 settlement Act but also offered more opportunity for Māori community to be engaged in various facets of fisheries management.

Ngāi Tahu the largest iwi (Māori tribe) in the South Island with the largest coastline was heavily involved in the final round of negotiations with the state to agree on a set of regulations governing the customary non-commercial fishing right (Cassidy, 2000). In 1998 the Fisheries (South Island Customary Fishing) Regulations were finally passed. The regulation defines the customary non-commercial rights that were initiated with the interim settlement of 1989.

Taiāpure and Mātaitai are Area Management Tools available to Tangata Whenua (indigenous people of the land) to help them sustainably manage their traditional fishing grounds. Temporary enclosures impose a temporary ban on taking nominated species or a restriction on nominated fishing methods to help restore depleted stocks. It is different from Marine reserves which are permanent and complete 'no-take' zones. In a taiāpure and mātaitai local fishing rules protect sustainability, but they are established, managed and protected by Tangata Tiaki (environmental guardians) appointed by Tangata Whenua. Mātaitai can be constituted and run entirely by Tangata Whenua, though in practice other interest groups are often drawn into co-management by the Tangata Tiaki. Commercial fishing is normally excluded from mātaitai reserves. Taiāpure are often managed in collaboration with local fishing stakeholders (recreational and commercial fishers) and commercial fishing continues but may be subject to the taiāpure rules.

Table 1.1: Established Taiāpure in New Zealand

Taiāpure	Region	Commencement Date	Approx. Area (km^2)
Waikere Inlet	Northland	15 / 01 / 1998	18
Kawhia Aotea	Waikato	08 / 06 / 2000	162
Maketu	Bay of Plenty	17 / 10 / 1996	54
Porangahau	Hawke's Bay	02 / 01 / 1997	61
Palliser Bay	Wellington	14 / 07 / 1995	3
Whakapuaka Delaware Bay	Nelson	21 / 03 / 2002	25
Akaroa Harbour	Canterbury	30 / 03 / 2006	43
East Otago	Otago	29 / 07 / 1999	22

Table 1.2: Mātaitai Reserves established in New Zealand

North Island Mātaitai Reserves	Location	Commencement Date	Approx. Area (km^2)
Aotea Harbour and adjacent harbours	Waikato	08 / 05 / 2008	40
Mt Maunganui and part of Tauranga Harbour	Bay of Plenty	25 / 09 / 2008	7
Raukokere	Bay of Plenty	12 / 08 / 2005	26
Horokaka	Mahia Peninsula	13/09/2012	4
Toka Tamure	Mahia Peninsula	13/09/2012	3
Te Hoe	Mahia Peninsula	13/09/2012	15
Marokopa	Waikato	13 / 01 / 2011	68
Hakihea	Gisborne	04 / 08 / 2011	4
Moremore	Napier, Hawke Bay	12 / 08 / 2005	16

South Island Mātaitai Reserves	Location	Commencement Date	Approx. Area (km^2)
Kaihoka and Anatori	Tasman	13 / 01 / 2011	5 and 15
Okarito Lagoon	West Coast	13/09/2012	19
Manakaiaua / Hunts Beach	West Coast	22 / 09 / 2011	<1
Mahitahi / Bruce Bay	West Coast	22 / 09 / 2011	1
Tauperikaka	West Coast	22 / 09 / 2011	<1
Okuru / Mussel Point	West Coast	22 / 09 / 2011	<1
Rapaki Bay	Banks Peninsula	18 / 12 / 1998	<1
Koukourarata	Banks Peninsula	15 / 12 / 2000	8
Wairewa / Luke Forsyth	Banks Peninsula	08 / 07 / 2010	6 (plus 1.5 km of the river)
Te Kaio	Banks Peninsula	16 / 12 / 2010	12
Waihao	South Canterbury	13/09/2012	4 (plus 33 km, in total, of the Waihao River, Hook River and Waituna Stream)
Moeraki	North Otago	16 / 12 / 2010	3
Puna-wai-Toriki (Hays Gap)	South Otago	03 / 04 / 2008	2
Waikawa Harbour / Tuma Toka	Catlins Coast	09 / 10 / 2008	7
Mataura River	Southland	12 / 08 / 2005	<1
Oreti	Southland	08 / 07 / 2010	16
Te Whaka a Te Wera	Stewart Island	03 / 12 / 2004	77
Horomamae	Titi Islands	08 / 07 / 2010	<1
Pikomamaku	Titi Islands	08 / 07 / 2010	<1
Kaihuka	Titi Islands	08 / 07 / 2010	<1

Source: Ministry of Primary Industries (2013)

The recognition of customary fishing rights in 1989 resulted in the increase interest from Māori communities in establishing mātaitai and taiāpure reserves to protect their fishing grounds. There are currently eight taiāpure and thirty mātaitai reserves established in New Zealand (Ministry Fisheries, 2013) (Table 1 and 2). This is a clear indication of the growing awareness among customary fishery owners to exercise their (kaitiakitanga) guardianship of their fishery resources. A significant number of established customary mātaitai reserves objectives are to protect shellfish population in the intertidal coastal areas. This is a direct result of the growing concern of the depletion of shellfish population in many coastal areas.

1.5 New Zealand Shellfish Fisheries

Shellfish are an important source of food for many people in New Zealand and are collected for recreational, commercial and Māori customary use. It is also a good indicator of the well being of the marine environment and performs important ecological services where it exists. The ability to harvest shellfish from beaches is highly valued by coastal communities. Shellfish are part of a group of species that are managed under the Quota Management System. The Fisheries Regulation 1996 section 19 set out the maximum number of shellfish which may be taken by any one person on any day.

Restoration of shellfish populations is becoming an increasing practice worldwide as natural populations are exposed to habitat loss or degradation and over harvesting (Gaffney 2006). In New Zealand, the number of people gathering shellfish in the North Island has increased significantly over the years, and this has resulted in many beach closures for shellfish gathering (Butler, 2005). In 2005, there were 12 beaches and coastal waters that had to be provisionally closed to allow shellfish fish stocks to recover. This was nearly twice the number closed in 2002 and three times the number in 1997, when four coastal areas were closed ((Ministry of Fisheries 2008). Around the Auckland region Eastern beach, Karekare beach and Cheltenham beach are closed for all shellfish gathering. In the Hauraki Gulf Area, the rāhui at Umupuia beach have been extended to October 2014 and Whangateau beach have been closed to collecting of cockles and pipi since October 2010 (Ministry Fisheries, 2012)

Many local iwi have used customary management tools such as a mātaitai reserve to try restoring shellfish stocks needed for customary use. In the North Island this includes Hicks Bay, Ohiwa Harbour, Mt Maunganui (became mātaitai reserve after temporary closure in

2005), Pukerua Bay and Wilsons Bay to Ngarimu Bay on Coromandel Peninsula (Ministry of Fisheries, 2008). In Canterbury, Rāpaki Bay, Koukourārata (Port Levy) and part of Kaikōura Peninsula are temporarily closed. Rāpaki Beach has the most significant population of *paphies australis* (pipi) in the Canterbury region and is one of only a few places in the South Island where pipi are found in substantial numbers. Koukourārata is traditionally an important site for cockles in the Canterbury region and cockle population has been on a decline since 1998 (Voller, 2003).

1.6 Study Sites

Māori Community customary fisheries at Rāpaki, Koukourārata (Port Levy) and Kaikōura are important in the history of customary fisheries in New Zealand. Rāpaki and Koukourārata (Port Levy) are the first two mātaitai reserves to be established in New Zealand, after the recognition of the customary management tools in the 1992 Fishery Act. Rāpaki the first mātaitai reserve was gazetted in December 1998 and two years later in December 2000 Koukourārata mātaitai reserves was established. In 2002, the Kaikōura rāhui (temporary closure) was the first to be established under the new Customary Fisheries Regulation. The Kaikōura Māori community has continuously extended the rāhui every two years. The current rāhui will expire in August 2014. The three Canterbury Māori communities are therefore, the first to be given the right to practice customary management tools after a lapse of about one hundred years. They have been practicing the use of customary management tools for the last fourteen years, yet very little empirical data are available to show whether they are sustainably managing shellfish in their customary fishing grounds.

1.6.1 Rāpaki Mātaitai

The small Māori community of Rāpaki is located about 4.5 km from Lyttleton heading south west towards Governors Bay (Figure 1.2). The village lies close to the sea, therefore kaimoana and the gathering of it has continually played an important role in the life of the community. The Rāpaki Mātaitai reserve is a traditional fishing ground for the people Te Hapū o Ngāti Wheke Rūnanga. It was one of the important fishing grounds of the early Māori because of the abundance of natural food. The area of the mātaitai reserve covers about 2.5 km^2 of coastline extending 0.3km^2 out into the Bay. At Rāpaki Cemetery sandy beach was the main site study for pipi and Cemetery and Aunties beach rocky shore was used to study cats eye. The non-reserve sites were Corsair Bay and Cass Bay (Figure 1.2).

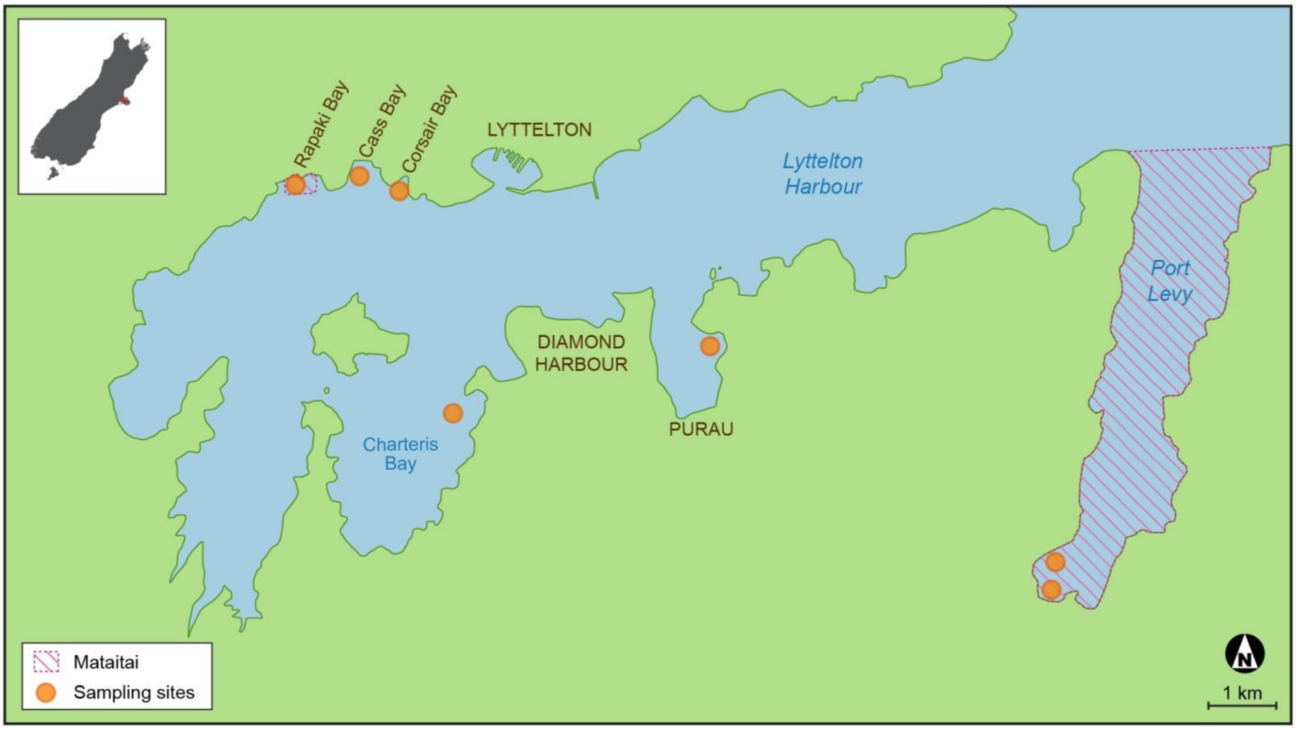


Figure 1.2: Location of study sites in Bank Peninsula

1.6.2 Port Levy (Koukourārata) Mātaitai

Port Levy Bay was first occupied by the Ngāi Tuahuriri sub tribe of Ngāi Tahu. The Bay was named Koukourārata by their chief Moki. In the mid-1800s, Koukourārata was the biggest Māori settlement in the Canterbury region with a population of about 400 people (Taylor 1948). The current population is now below 100 as more of its people are now living in Christchurch (Rewi 2009).

Port Levy is a long narrow inlet of the Banks Peninsula (Figure 1.3). It is a long sheltered bay with widespread mudflats. The rocky headlands have boulders of different sizes and are mostly populated by filter feeding organisms in the intertidal region. The rocky shore has various intertidal organisms that can tolerate exposure to silt based sediments and turbid conditions. The rocky shore biota consists of cockles, (*Austrovenus stutchburyi)* cat's eyes (*Turbo smaragdus*) and camouflage crabs. Species diversity increases towards the low tide region (Marsden, 2005). Cockles are the dominant species in the soft shores at Port Levy (Marsden, 2005).

Pa village cockle bed about 30-40 metres in length is the main customary harvesting site (Voller, 2003) and lies in front of the village. Fernlea towards the north is the other customary cockle bed (Figure 1.2). These two gravel beaches were chosen to assess the population of cockles because they are important customary harvesting sites. Two similar sites at Charteris Bay and Purau Bay were sampled as non-reserve sites (Figure 1.2).

Figure 1.3: Koukourārata Mātaitai reserve. Source: (Ministry of Fisheries, 2008)

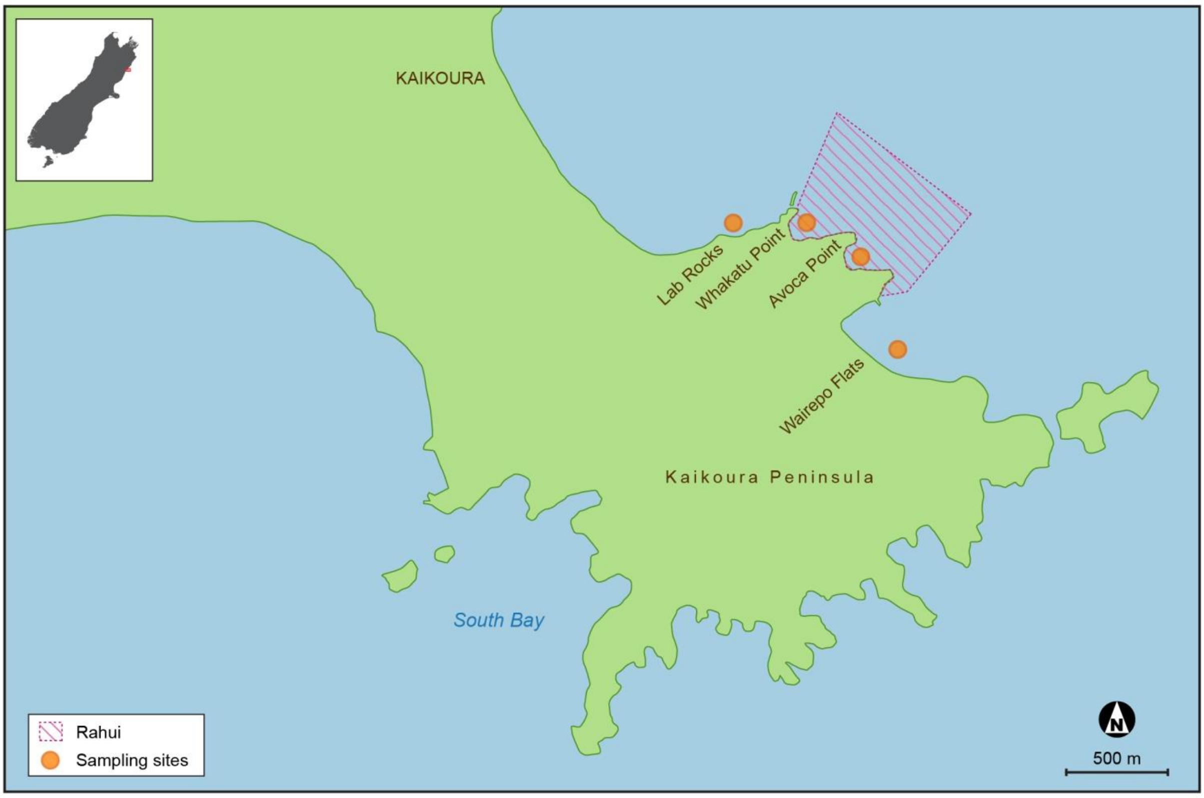


Figure 1.4: Location of study sites on the Kaikōura Peninsula

1.6.3 Kaikōura (Takahanga Marae)

The Te Rūnanga o Kaikōura rāhui was established over a small area of the coastline on the north side of the Kaikoura peninsula. It closes the Waiopuka reef between the North wharf near Whakatu Quay and the Old Wharf (Figure 1.4). The Kaikōura coasts are renowned for its rocky shores, a combination of rocky headlands, wave–cut platforms divided by channels, variable bedrock reefs and boulder shores (Schiel, 2004). The bedrock and boulder shores consist mostly of resistant greywacke, though mixes of other sedimentary rock types (sandstone, siltstone and limestone) are also found in the Kaikōura Peninsula.

Much of the Kaikōura coastline is dominated by macroalgal communities in either wave exposed and sheltered conditions (Menge, et al. 1999). Although macroalgae are the dominant habitat occupiers, there are several sites on this coastline where filter feeding invetebrates are abundant (Schiel, 2004). Most of Kaikōura's intertidal invertebrates are shellfish, with more than 30 mollusc species (comprising various grazers, filter feeders, scaveners and carnivores) often recorded from any one reef (Rasmussen, 1965). Key invertebrates found intertidally are periwinkles (*Austrolittorina cincta* and *A. antipodum*), the common topshell (*Melagraphia aethiops*), cat's eye (*Turbo smaragdus*), dentate limpet (*Cellana denticulata*), and the large barnacle *Epopella plicata* (Marsden, 2004).

The multiple and inconsistent nature of the coastal physical environment, as well as the specific hydrological conditions at Kaikōura explain the biologically diverse marine ecosystem (Rasmussen, 1965). Two sites within the rahui at Avoca Point and Whakatu Point were chosen to study the population of *Turbo smaragdus* and compared two similar sites outside the reserve at Lab rock and Wairepo flats (Figure 1.4).

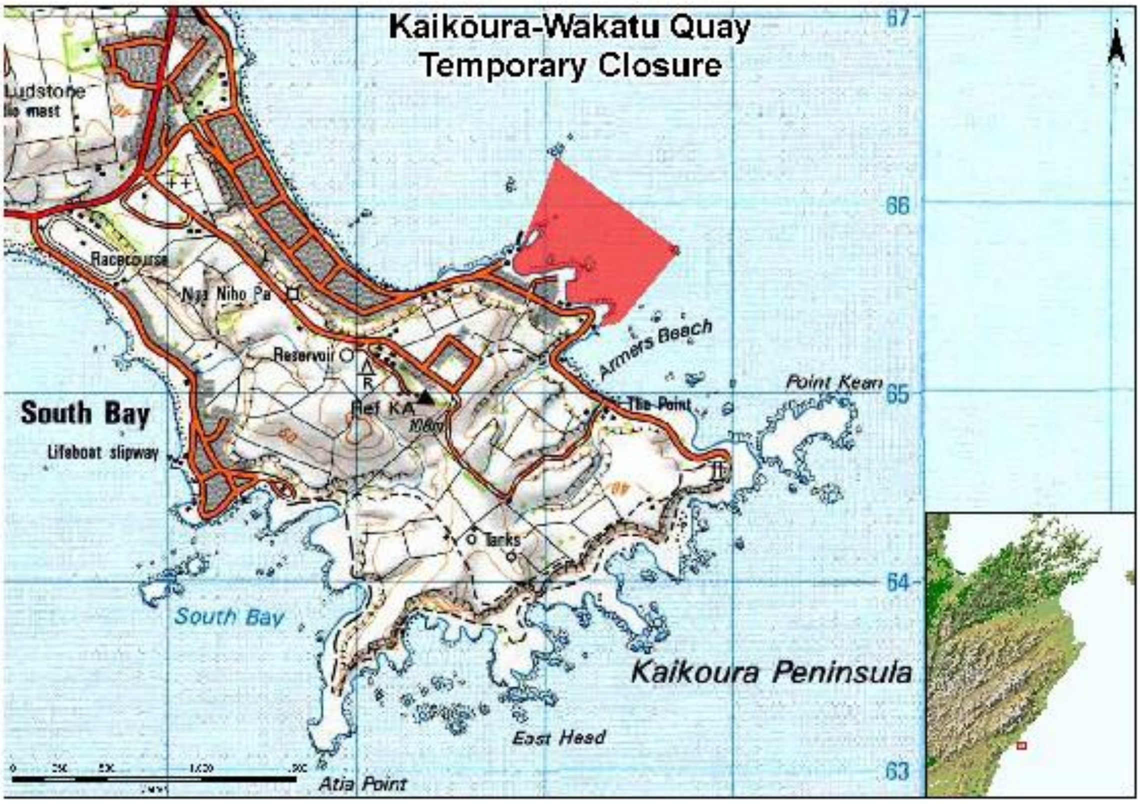


Figure 1.5: Kaikōura reserve. Source: (Kaikōura Coastal Marine Guardians, 2008).

1.7 Objectives of the Research

This thesis research will follow Māori customary management of shellfish in three different Ngāi Tahu communities in the Canterbury region and investigate the effectiveness of the customary management tools (mātaitai and rāhui) in protecting shellfish population and allowing it to regenerate in a sustainable manner. The thesis will use scientific research methodologies as well as Traditional Ecological Knowledge of kaumatua and kaitiaki to evaluate the conservation values of customary management. Although these customary management practices have been protecting shellfish for fourteen years, there are very little empirical data to show whether or not it is successful in meeting one of their stated objective of providing sustainable fisheries.

This thesis study will specifically explore three questions about Community Customary Fishery Management in New Zealand.

- Is there a difference in the abundance, density, size structure, shell length and condition index of shellfish population in reserve sites compared to non-reserve sites?
- How successful is the established Canterbury community customary marine reserves in terms of conserving and sustaining shellfish populations
- How can Indigenous knowledge compliment science in monitoring the state of customary reserves?

1.8 Thesis Structure

This chapter introduces the growing interest in the functions of community customary fisheries management system and its ability to effectively control access to fishery resources. It provides the history of fisheries management in New Zealand including the failure of the Centralised Management approach, continued debate about the success of Individual Transferable Quota and the revival of the Māori customary fisheries management practices. Finally, it poses three broad questions which provide the preliminary overview of the issues that this thesis will address.

Chapter 2 discusses the scientific evaluation of *Paphies australis* population at Rāpaki reserve and corresponding non-reserve site at Corsair Bay

Chapter 3 discusses the scientific evaluation of *Austrovenus stutchburyi* population at two reserve sites at Port Levy and corresponding non-reserve sites at Fernlea and Purau Bay.

Chapter 4 provides the scientific evaluation of *Turbo smaragdus* population in the three customary reserves at Kaikōura, Rāpaki and Port Levy as well as corresponding non-reserves sites.

Chapter 5 discusses the cultural evaluation of the three reserves by the kaumatua (elders) and kaitiaki of the three reserves. Chapter 6 provides a general discussion of the findings of the research and its implication to the customary fisheries management in New Zealand.

Chapter 2: Evaluation of *Paphies australis* populations in Rāpaki reserve and non-reserve site at Corsair Bay

2.1 Introduction

Bivalves belong to the class Bivalvia or (Lamellibranchia), Phylum Mollusca. There are about 10,000 bivalve species in the class Bivalvia, second only to gastropods in terms of molluscan diversity (Eversole, 1989). Bivalves are entirely aquatic with the majority being marine (Young and Thompson, 1976). Most bivalves are filter feeders and have highly modified gills to filter phytoplankton. They commonly aggregate in very large numbers forming shellfish beds in marine, estuarine and freshwater habitats.

Many bivalve species (e.g. clams) are infaunal, and burrow in sandy to muddy sediments but some are epifaunal, and attach themselves to a hard substrate (e.g. mussels and oysters). Their high biomass make them an important ecological element of soft sedimentary environments and therefore a comprehensive knowledge of the population dynamics of these species is essential for evaluation of fisheries management strategies (Hooker, 1995).

Bivalves (clams, mussels, scallops and oysters) have historically formed a significant part of the human seafood diet as well as providing important ecological roles in marine and freshwater ecosystems. The biggest group of infaunal bivalves are the clams which have attracted a substantial amount of research, because of their commercial, cultural and ecological importance (Hooker, 1995).

In many countries of the world coastal clam species have been harvested and long-term harvest records have been kept (Bourne, 1989). These records indicate that demand for shellfish has continued to grow, while natural harvests have declined. They support large fisheries around the world and about 70 species world-wide are considered as major regional fisheries from which twelve are intensively cultured (Manzi and Castagna, 1989).

The Family Mesodesmatidae is represented by a few genera and species of surf clams, which include the genus *Paphies*. Four species of surf clams in this genus are found in the marine waters of New Zealand (Smith, et al, 1989). These include the northern tuatua (*Paphies subtriangulata*), deepwater or southern tuatua (*Pahies donacina*), pipi (*Paphies australis*), and toheroa (*Paphies ventricosa*).

2.2 Tuatua

The northern tuatua (*P.subtriangulata*) is extensively distributed around New Zealand in localised abundant populations, but mainly occurs around the North Island, and at more scattered locations in the northern South Island, Stewart Island, and the Chatham Islands (Grant, 1994)). *P. subtriangulata* is a surf clam that lives on more open exposed sandy beaches with shifting sands (Morton and Miller, 1973). It is the most inshore species of surf clam in New Zealand (Cranfield, et al. 1994).

Southern tuatua *(P. donacina*) are found throughout the South Island and the north coast of Stewart Island, and the lower part of the North Island (Beu and De Rooij-Schuiling, 1982). They can be abundant in the low intertidal and shallow subtidal zones off sandy beaches of the eastern South Island such as Pegasus Bay in the Canterbury coastlines and the Otago region (Miller, 1999).

The tuatua is smooth and wedge shaped with a thick shell similar in shape to toheroa, but smaller in size, reaching about 90 mm in length (Bradford, 1998). Tuatua sexually matures when around 50mm in shell length (Marsden, 1999). Their recruitment takes place in the mid intertidal zone, with individuals moving to lower tide zones over time (Grant, 1994; Marsden, 2000). Dense tuatua beds are found in the low intertidal to the shallow subtidal zones to a depth of 4 m. Like other intertidal shellfish, tuatua are an important customary species taken as kaimoana. The oral tradition, as well as the numerous middens of tuatua shells around the coastline, clearly indicate this fishery has been important to Māori for at least several hundred years (Grant, 1994). The current level of recreational harvest and its impact on the status of tuatua beds are unknown (Boyd, et al, 2004). There are concerns about the depletion of popular tuatua beds in some areas, whereas in other areas, it appears they are in a healthy state (Boyd et al, 2004).

2.3 Toheroa

Toheroa populations were more widespread in the past, today they are found in Northland, with smaller populations on the Kapiti coast and in Southland (Morrison & Parkinson, 2001). Adult toheroa normally have shells greater than 150 mm and is the largest of the Mesodesmatidae family (Hooker, 1995). The shells are thin and have a distinct gap at each end of the shell margin which makes them different from pipi and tuatua. Toheroa is found in the intertidal zone on fine sand beaches, fully exposed to surf (Rapson, 1952; Cassie, 1955). Toheroa are active burrowers, living 10-20 cm below the sand. When feeding they extend their siphon past the surface sand to filter plankton out of the water. The toheroa was once considered the prime seafood delicacy of New Zealand and has supported a large fishery in the past (Redfearn, 1974). Toheroa have long been an important food for Māori and has been subjected to harvesting since the late 1800s, both from recreational and commercial sectors leading to decline in populations nationally. Restrictive regulations on the length of recreational seasons, bag limits, methods, and minimum legal size did not improve the restoration of populations, and by 1989 all harvesting was banned throughout New Zealand. All beaches inhabited by toheroa are currently managed by local Māori, and toheroa harvest permits are given out by Māori kaitiaki representing appropriate runanga (Beentjes, 2009)

2.4 Pipi

Pipi have a white elongated symmetrical shell with the apex at the middle. It is covered with a thin yellow periostracum. Unlike other *Paphies* species which are more abundant on open coasts, pipi are restricted to sandbanks and the mouths of harbours where they occur in the top 10 cm of coarse sediments (Morton and Miller, 1973). Hooker (1995) found that pipi may use water currents to disperse actively within a harbour, but in general they are considered to be sedentary once they have settled.

The pipi are important customary seafood for Māori, they are an important part of a recreational harvest and a small commercial fishery (Haddon, 1989). Despite their importance there has been little published information (Hooker, 1995; Mamat, 2010). Limited information on pipi can be found in general studies on estuaries and harbours around New Zealand (Grange, 1977; Kilner and Akroyd, 1978). The studies on pipi have focussed mainly on its biological and ecological aspects, and most studies have been done in the North Island. A few studies have been done on pipi populations on beaches; most studies have been carried out in harbours and bays using SCUBA and measurements recorded under water (Hooker, 1995). Most of the information on the distribution and abundance of pipi is general in nature, the commercial and recreational databases providing information on its relative abundance by region (Boyd, 2003).

Growth is seasonal and occurs mainly during spring and summer (Hooker, 1995). There is no minimum legal size for pipi, although every fishery most likely favours larger pipi, greater than 40 mm length (Ministry of Fisheries, 2011). Pipi are available for harvest year round, so there is no clear seasonality in the fishery (Ministry of Fisheries, 2011). Pipi was introduced to the Quota Management System (QMS) in 2005 with most of the commercial landings in the North Island. The recorded landings in 20005-2006 and 20006-2007 were 136.7 tonnes (t) and 134.7 t respectively (Ministry of Fisheries, 2011). The pipi recreational allowance for the South East coast of the South Island (PPI 3) is 9 t, and the customary allowance is also 9 t (Ministry of Fisheries, 2011). There is no quantitative information on the level of recreational and customary harvest (Ministry of Fisheries, 2011).

2.5 Study Objectives

Rāpaki mātaitai reserve is one of the few places in the Canterbury region where pipi are found. The aims of the management of Rāpaki mātaitai are to maintain and improve the local fishery, and to ensure the sustainability of the resources and its environment. The Fisheries (South Island Customary Fishing) Regulations provided the kaitiaki of Rāpaki with the ability to manage fishing within the mātaitai through bylaws. The bylaws concerning the harvest of pipi states that a person is only allowed to take 50 pipi from the mātaitai reserve each day.

This research measured pipi abundance, population size structure, distribution and ratio of juvenile and adult population in the Rāpaki mātaitai reserve and compared it to the non-reserve site at Corsair Bay. Corsair Bay is about 2km away from Rāpaki reserve and is the closest beach that is inhabited by pipi. The data from these two sites were compared to assess if the pipi population at Rāpaki reserve was different from Corsair Bay and if there was sufficient pipi to meet the demands of customary harvest. This study will provide some insight of the state of shellfish population by comparing the pipi population biology between the reserve site at Rāpaki to non-reserve site at Corsair Bay.

This study is an essential first step towards a better understanding of how the pipi population has benefitted from the protection of the mātaitai reserve. Pipi population information from this study could provide a baseline data upon long term data set could be based. According to Pawley (2010) data on intertidal shellfish population dynamics has to date received little attention and is a research area of importance for sustainable management.

2.6 Methods

Preliminary surveys were carried out at the reserve site at Rāpaki Cemetery beach and non-reserve site at Corsair Bay to determine the location of the pipi beds on the beach and see if there were seasonal variations in the abundance, distribution and size of pipi on the upper and lower shores. Preliminary surveys were carried out in spring October 2010, summer December 2011 and autumn April 2011.

A 100 m measuring tape was used as a transect placed perpendicular to the shore from a known high tide to the low tide mark. During the preliminary survey, two transects placed 10 m apart were used to sample the beach. Samples were taken every 10 m, starting at the 10 m mark on the measuring tape down to 50 m. At every 10 m interval, two samples were collected from each transect. Transects were sampled at low tide with a 12.5 cm diameter core to determine the abundance, size structure and distribution of pipi on the beach. The core was randomly placed within 5 m at each side of the transect. The samples were dug to a depth of 10 cm and sieved using a 0.5 mm mesh. All pipi were counted and measured using callipers to the nearest 1 mm. Numbers and lengths of pipi were recorded. The total area of the beach surveyed was 1000 m^2 and 20 samples were collected at each sampling time.

The main survey was carried out in winter August 2011 and summer December 2011. Information collected from the Māori community at Rāpaki, indicated that most shellfish harvesting was done during the summer months and very little if any were done in winter. Winter and summer surveys were therefore carried out to investigate the difference in abundance, density and size structure of shellfish between the reserve and non-reserve sites and if there are seasonal changes that were related to harvesting.

I discovered during the preliminary surveys that few pipi were found 10 m from the top shore. Only 9 individuals were collected in summer, while in spring and autumn there were none. Therefore for the main survey, samples were collected starting at the 20m distance from the top of the shore. Transects were increased from two to four, and a total of eight samples were collected from each 10 m interval, instead of four. The transects were increased to allow more pipi to be collected as it was obvious from the graph of distribution of the sample mean that not enough were collected during the preliminary surveys.

The process of collecting pipi was the same as described in the preliminary survey. The total area surveyed during the main survey was 2000 m^2 and 32 samples were collected from the reserve site at Cemetery beach, while 24 samples were collected at the non-reserve site Corsair Bay. There was no pipi collected from 50 m at Corsair Bay in both the preliminary and main survey, resulting in differences in number of samples. The comparisons of abundance, density, distribution and size structure between the reserve and non-reserve sites were therefore limited to the 40 m shore distance.

To determine the ratio of juveniles and adults in the populations at Cemetery beach (Rāpaki reserve) and at Corsair Bay (non-reserve) the total population collected in each season were classified into juvenile and adult. At Cemetery beach, the adult pipi collected from the 50 m shore distance were included in the comparison. In this study, sexual maturity was used to distinguish the juvenile from adult pipi. All pipi less than 40 mm in shell length were classified as juvenile, and those with a shell length greater than 40 mm were classified as adult. According to (Hooker and Creese, 1995c) pipi sexually mature at about 40 mm shell length. All pipi greater than 40 mm were therefore considered being harvestable. The ratio of juvenile and adult population was displayed on a pie chart. A pie chart is the better method of displaying categorical data that have no logical sequence (Dytham, 2011).

The condition index of pipi at Cemetery beach were measured and compared to condition index at Corsair Bay non-reserve site. Condition index was determined as a proxy of organism health, and to compare the health of the bivalves among sites and over time (Davenport and Chen, 1987). A total of 15 pipi from each site measuring 10-40 mm were chosen to measure condition index. Measurements made on each individual pipi include total weight (0.01g), total length (nearest 0.05 mm) and wet shell weight (nearest 0.01 g). Pipi were opened, and the meat removed and wrapped in aluminium foil. The wrapped tissue and the wet shell were then dried at 60˚C for 48hrs in an oven. The condition index of cockles (C.I.) was calculated as the ratio of the dry weight of the flesh/ dry weight of shell x 100 (Walne, 1976).

2.7 Statistical Analysis

All analyses were performed using MINITAB 16 statistical software. One and Two- way Analysis of Variance (ANOVAs) were used to compare the variation between reserve and control sites in terms of abundance, shell lengths and condition index. All abundance, shell lengths and condition index data were evaluated using the means, standard deviation and standard error (Parker, 1973). Population size structure was evaluated using size frequency histograms. Significant differences ($P < 0.05$) among shore distances and between sites were further analysed by Tukey honest significant difference (HSD) test. Categorical variables like juvenile and adult population were analysed using Chi – Square Goodness of Fit Test.

2.8 Preliminary Survey Results

Abundance and Density

The highest density of pipi at Corsair Bay was 21 per replicate or 1768 per m² compared to 59 per replicate or 4968 m² at Cemetery beach. The abundance of pipi was consistently significantly higher ($P > 0.05$) at the 40m zone at Cemetery beach compared to the non-reserve site at Corsair Bay during the preliminary surveys (Appendix 1: Figure A 1.1), (Table A 1.1-1.3). At Cemetery beach, the abundance increased significantly ($P <0.05$) with distance down to the lower shore (Appendix 1: Figure A 1.1). In contrast, the abundance at Corsair Bay decreased at the 40m zone in both summer and autumn with a slight increase in spring (Appendix 1: Figure A 1.1). A Pearson's correlation analysis revealed that pipi abundance had significant positive correlations with distance to the lower shore at Rapaki reserve. The abundance between sites and seasons was not statistically resolved due to variability in the results**.** Further investigation was therefore carried out by increasing the transects and samples in the main survey in winter and summer.

Shell Lengths

The mean shell lengths of pipi (*Paphies australis*) increased with distance down the lower shore at both Cemetery beach and Corsair Bay during all the preliminary surveys (Appendix 1: Figure A 1.2). The mean shell length of pipi at Corsair Bay was greater than Cemetery beach at the 20-40 m shore distance in all preliminary surveys except in autumn where Cemetery beach had a higher mean shell length at the 40 m shore distance (Appendix 1: Figure A 1.2).

Condition Index

The mean condition index of pipi generally decreased as shore distances increased down to the lower shore. This trend was evident in both Cemetery beach and Corsair Bay during all the preliminary surveys in spring, summer and autumn (Appendix 1: Figure A 1.3). Pipi from Cemetery beach consistently had a higher condition index than Corsair Bay at the 20 m–30 m shore distances in the entire preliminary surveys (Appendix 1: Figure A 1.3**)**. The differences were statistically significant in summer at 20 m (Appendix 1: Table 1.6) and in autumn (Appendix 1: Table 1.7) at both the 20 m and 30 m shore distances ($P < 0.05$). At 40 m, Corsair Bay had a slightly higher condition index in spring and autumn, but the differences were not statistically different ($P > 0.05$). Seasonal comparison of condition index at the 40 m shore distance where mature adults occur, indicate that autumn condition index was the highest at both Cemetery beach and Corsair Bay (Appendix 1: Figure A 1.3).

Adult and Juveniles

In the preliminary survey, most juvenile pipi were found at the 20 m and 30 m distance from the upper shore, while the adults were found at the lower 40 m and 50 m zone. At Cemetery beach, the percentages of juvenile and adult population were very similar with the juvenile population slightly higher than the adult in all the three seasons (Appendix 1: Figure A 1.4). At the non-reserve site in Corsair Bay, the population was dominated by juveniles (< 40mm shell length) in all the three seasons (spring 97%, summer 92% and autumn 96%) (Appendix 1: Figure A 1.4).

2.9 Main Survey Results

2.9.1 Abundance and Density

The densities of pipi during the main survey ranged from 1-47 individuals per replicate or (84-3957 per m²). The highest density at Corsair Bay was 21 per replicate or 1768 per m² compared to 47 per replicate or 3957 m² at Cemetery beach. A total of 567 pipi were collected from Corsair Bay at the 20-40 m shore distance during the main surveys compared to 753 at Cemetery beach. These differences were not stastically different (P > 0.05). It was apparent from the winter and summer results (Figure 2.1) that the mean abundance of pipi at the 20 m and 30 m shore distance at Corsair Bay were higher than Cemetery beach.

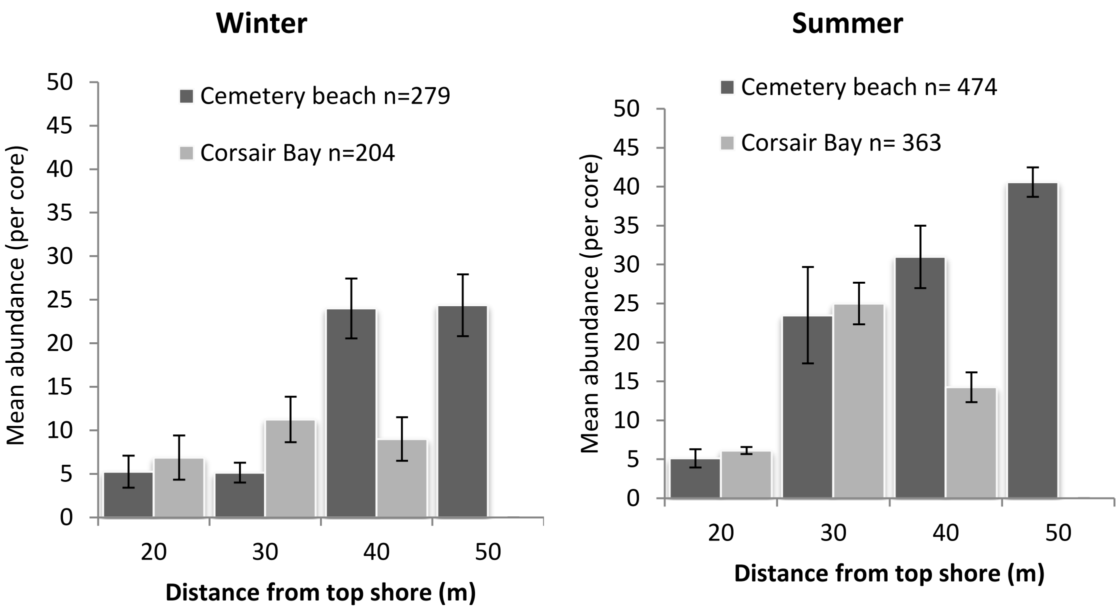


Figure 2.1: ***Paphies australis*** **mean population abundance(± s.e.) collected at different shore distances from Cemetery beach (reserve) and Corsair Bay (non-reserve) during winter August 2011 and summer December 2011**

There were no significant statistical difference in abundance at the 20 m zone in both winter and summer, but at the 30 m shore distance in winter abundance at Corsair Bay was significantly different (P < 0.05) as indicated by the one way ANOVA result (Table 2. 1). At the 40 m shore distance, the mean abundance were evidently more than twice higher at Cemetery beach compared to Corsair Bay during both winter and summer (Figure 2.1). The differences in abundance were statistically highly significant (P < 0.01) as indicated in (Tables 2.1 and 2.2).

The result displayed by the histogram (Figure 2.1) indicated that at Cemetery beach, the abundance increased with distance down the lower shore. In contrast, the abundance at Corsair Bay decreased at 40 m in both winter and summer. This trend was also observed during the preliminary survey. Comparing the increase in abundance at the shore distance from 10 m to 40 m between Cemetery beach and Corsair Bay by one way ANOVA indicated that the increase at Cemetery beach was significant ($P < 0.05$).

In both winter and summer the abundance was significantly different between the shore distances. Tukeys HSD post hoc test indicated that at the 40 m shore distance at Cemetery beach abundance was significantly different ($P < 0.05$) and higher than all shore distances at Corsair Bay. There was also a significant interaction between shore distances and sites. The significant interaction and differences between the shore distances were due to the high abundance at Cemetery beach at the 40 m shore distance.

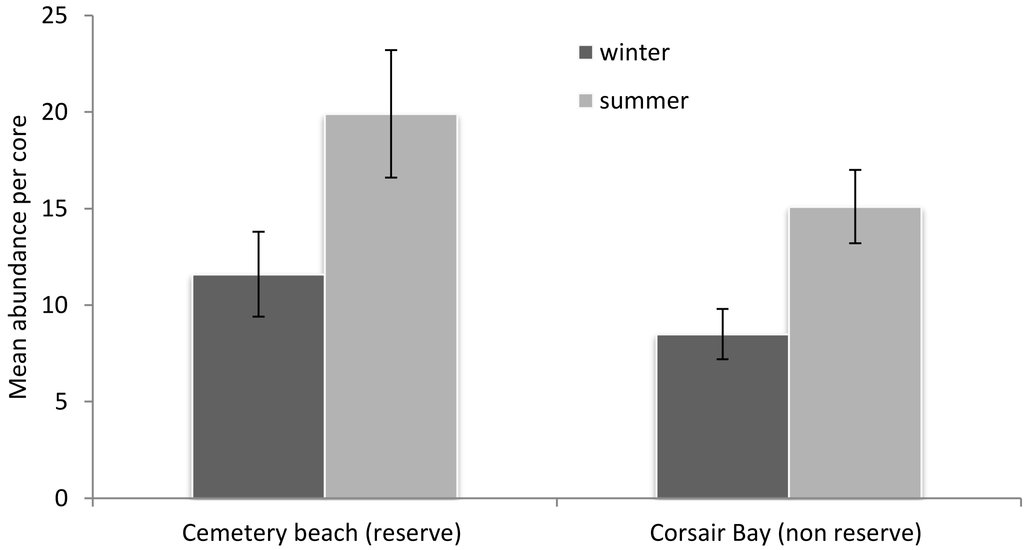


Figure 2.2: *Paphies australis* mean population abundance(± s.e.) from within the reserve at Cemetery beach and within non-reserve at Corsair Bay during winter August 2011 and summer December 2011

The result displayed by the histogram (Figure 2.2) showed that pipi abundance increased significantly in summer at both Cemetery beach and Corsair Bay. At Cemetery beach the significant level (P) was 0.043 while at Corsair Bay it was 0.006

Table 2.1: Result of 1 way ANOVA for average population abundance at different shore distances in the reserve and non-reserve sites during the winter August 2011 survey. (Df, degrees of freedom; MS, mean squares; P, probability level; NS, non-significant; S, significant).

Source of variation	df	MS	F	P	significance
Shore distances					
20m	1	10.6	0.27	0.612	NS
Error	14	39.3			
30m	1	150.1	4.62	0.049	S
Error	14	32.5			
40m	1	900	12.52	0.003	S
Error	14	71.9			

Table 2.2: Result of 1 way ANOVA for average population abundance at different shore distances in the reserve and non-reserve site during the summer December 2011 survey.

Source of variation	df	MS	F	P	significance
Shore distances					
20m	1	4	0.62	0.442	NS
Error	14	6.4			
30m	1	9	0.054	0.827	NS
Error	14	181			
40m	1	1122.3	14.3	0.002	S
Error	14	78.5			

Table 2.3: Result of 2 way ANOVA for average population abundance at different shore distances in the reserve and non-reserve site during winter August 2011 and summer December 2011.

Source of variation	df	MS	F	P	significance
Winter					
Shore distances	2	512.0	12.6	0.001	S
Reserve & non reserve	1	117.2	2.9	0.09	NS
Interaction	2	442.6	10.85	0.001	S
Summer					
Shore distances	2	1672.3	18.8	0.001	S
Reserve & non reserve	1	261.3	2.9	0.09	NS
Interaction	2	4297.7	4.85	0.001	S

2.9.2 Shell Lengths

The mean shell length of pipi increased with distance down the lower shore at both Cemetery beach and Corsair Bay during both the summer and winter surveys. This was similar to the result obtained during the preliminary surveys. There was no pipi 50 m down the shore distance at Corsair Bay during the main surveys. The mean shell lengths of pipi at Corsair Bay were greater than Cemetery beach at the 20-40 m shore distances in winter and at the 30-40 m shore distances in summer (Figure 2.3). The differences were obvious at the 40 m shore distance in both winter and summer (Figure 2.3). For example in winter the mean shell length at Corsair Bay was 37.5 mm compared with 18.9 mm at Cemetery beach. In summer, the mean shell length of pipi at Corsair Bay was 42.7 mm while Cemetery beach pipi recorded a length of 24.4 mm. In both seasons, the differences were highly significant (P= 0.001). The result of comparisons of seasonal differences of mean length within the reserve and non-reserve sites indicated that variation between seasons were not significant.

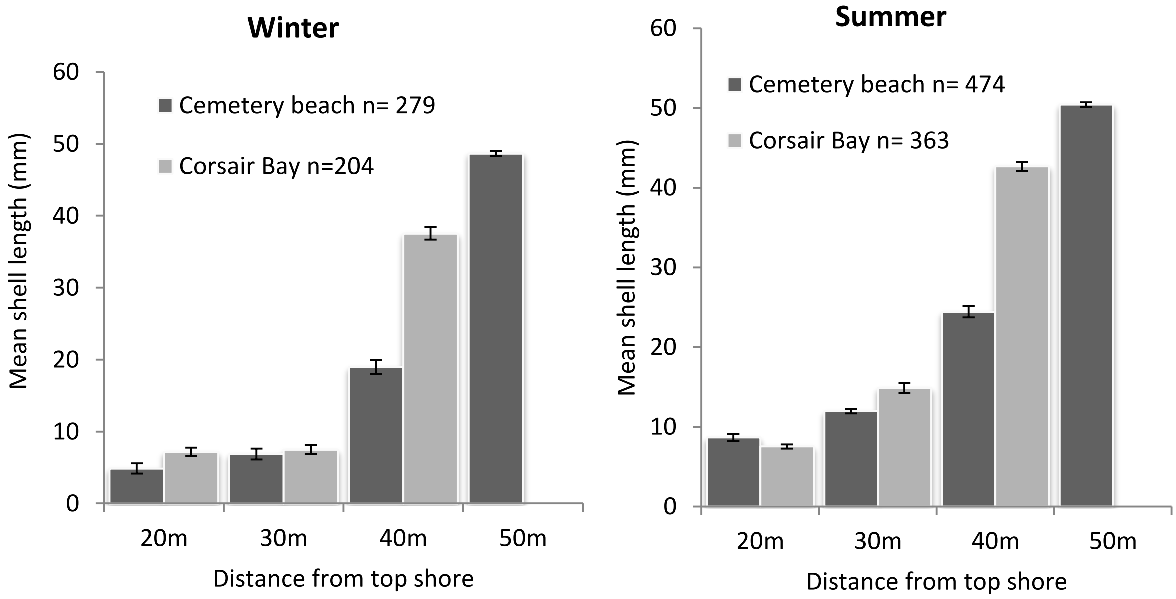


Figure 2.3: Mean shell lengths of pipi (*Paphies australis)* at Rapaki reserve and Corsair Bay during the main surveys in winter August 2011 and summer December 2011.

There were increases in mean shell lengths at both sites in summer, but this increase was not significant. The differences in total shell lengths between Cemetery beach and Corsair Bay also were not statistically different (P > 0.05) (Table 2.4).

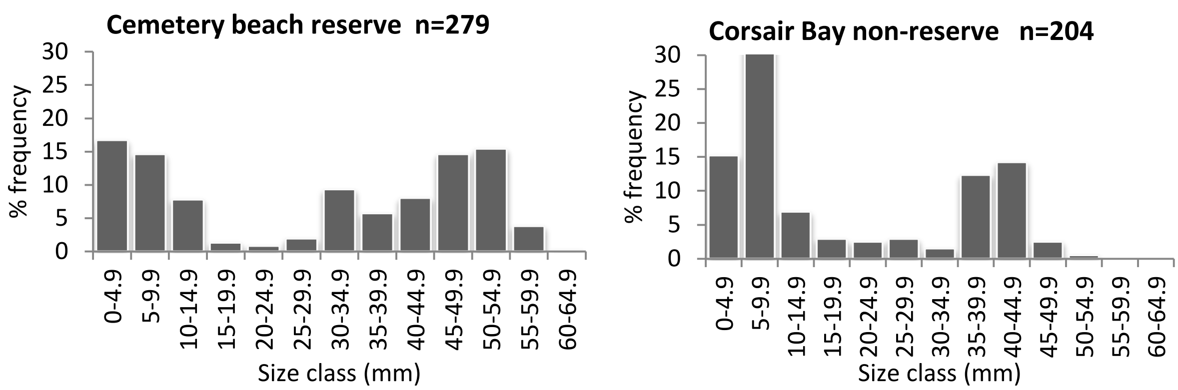
Table 2.4: Result of 1 way ANOVA for average total shell lengths at the Cemetery beach and non-reserve site at Corsair Bay during the main surveys in winter and summer.

Source of variation	df	MS	F	P	Significance
Winter					
Reserve & non reserve	1	32120	0.01	0.920	NS
Error	4	2782136			
Summer					
Reserve & non reserve	1	38721	0.01	0.943	NS
Error	4	6742268			

2.9.3 Size Structure

In the main survey, both Cemetery beach and Corsair Bay pipi had a bimodal length frequency distribution (Figure 2.4). In winter, the modes at Cemetery beach were not as well distinguished as Corsair Bay. The first mode at Cemetery beach occurred at length class 0-4.9 mm the second at 30-34.9 mm and a third at 50-54.9 mm. About 16% of the population were of shell length class 0-4.9 mm and about 15% were 50-54.9 mm (Figure 2.4).

Winter Survey



Summer survey

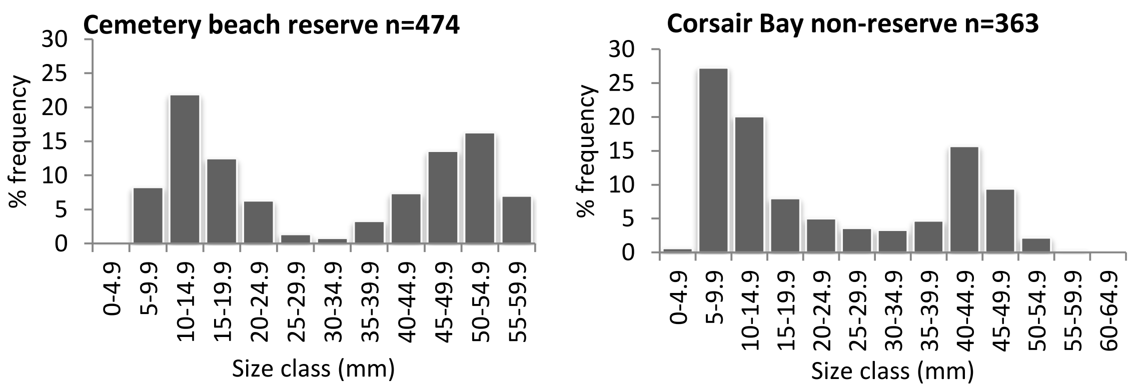


Figure 2.4: Size frequencies of pipi at Cemetery beach (reserve) and Corsair Bay (non-reserve) from combined samples in winter August 2011 and summer December 2011.

At Corsair Bay, the first mode was clearly distinguished, occurred at 5-9 mm and the second at 40-44.9 mm. About 39% of the pipi population were of shell length 5.9 mm, and about 14% were 40-44.9 mm. Cemetery beach had a stronger presence of the large adult pipe (> 40 mm) than Corsair Bay in winter. For example at Cemetery beach, 42% of the pipi population were (> 40mm) compared to 17% at Corsair Bay (Figure 2.4).

In summer at Cemetery beach the first mode occurred at 10-14.9 mm and the second at 50-54.9 mm, while at Corsair Bay, the first mode occurred at 5-9.9 mm and the second at 40-44.9 mm. About 22% of pipi at Cemetry beach were of shell length 10-14.9 mm and 16% were 40.44.9 mm. At Corsair Bay, 27% of the population were of shell length 5.9 mm, and about 15% were 40-44.9 mm. Cemetery beach again had a stronger presence of the large adult pipe (> 40 mm) than Corsair Bay in summer (Figure 2.4). For example, 46% of the pipi population sampled in summer at Cemetery beach were greater than 40 mm compared to 28% at Corsair Bay

Comparisons of large individuals within Cemetery beach and Corsair Bay indicated that proportions of large individuals (> 40 mm) had also increased in summer. Both Cemetery beach and Corsair Bay showed a lack of intermediate pipi size (20-30 mm) in length size in both seasons. In winter, Corsair Bay had a strong mode of juvenile pipi (5.9 mm). About 38% of the entire population were between size class (5-9.9 m). In winter, it was also obvious that both Cemetery beach and Corsair Bay had a significant number of juvenile pipi between 0-4.9 mm. At Cemetery beach, the frequency was 17 % compared to 15% at Corsair Bay.

2.9.4 Condition Index

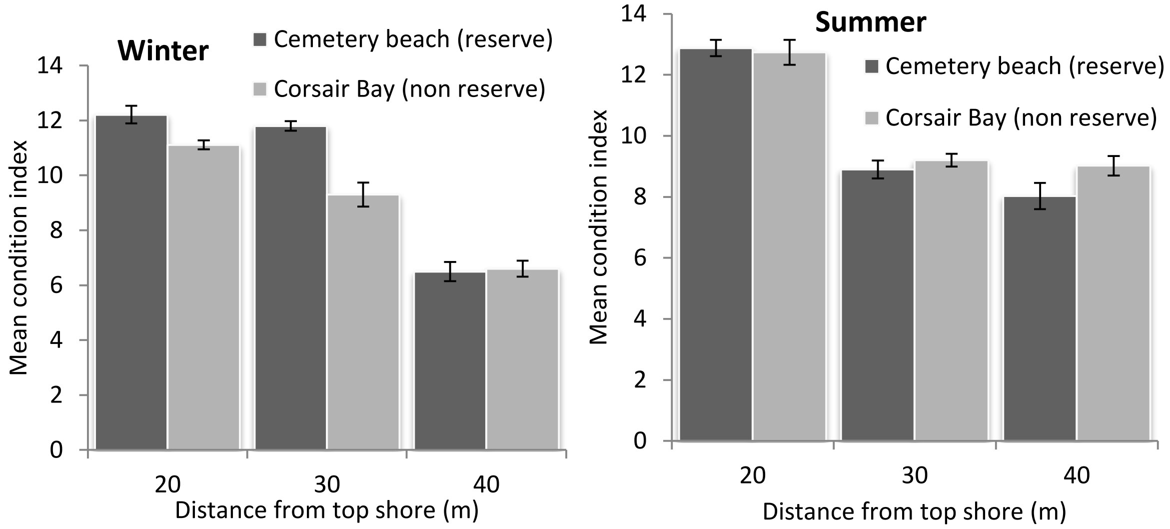


Figure 2.5: Mean condition indices (± s.e) at the 20m, 30m and 40m shore distances during the main surveys in winter August 2011 and summer December 2011

The mean condition index of pipi generally decreased down to the lower shore from the value of 12.2 to the lowest value of approximately 6 (Figure 2.5). This trend was apparent both at Cemetery beach and Corsair Bay in winter and summer. The lowest value of condition index was recorded in winter at 40 m down the shore (Figure 2.5).

In winter Cemetery beach, had higher condition index than Corsair Bay at the 20 m–30 m shore distances but was slightly less than Corsair Bay at 40 m (Figure 2.5). The higher condition index at Cemetery beach at the 20 m and 30 m distance was significant ($P < 0.05$), (Table 2.5). At the 40 m shore distance, summer condition index was higher than winter at both Cemetery beach and Corsair Bay (Figure 2.5). At Cemetery beach condition index was 6.5 in winter and 8.0 in summer while Corsair Bay had 6.6 and 9.0 respectively. Pipi at this shore distance were mostly adult (> 40 mm) therefore the condition index would be affected by spawning.

The result of the 2 way ANOVA (Table 2.7) indicated that there were highly significant differences in condition index both at the shore distances and between the sites ($P= 0.001$). The interaction of shore distances and sites were also significant. Tukeys HSD post hoc test indicated that the condition index in the 20 m shore distance at Cemetery beach was significantly higher than all other shore distances.

Table 2.5: Result of 1 way ANOVA for pipi condition index at the 20m, 30m and 40m shore distances at Cemetery beach (reserve) and Corsair Bay (non-reserve) during the winter August 2011 survey.

Source of variation	**df**	**MS**	**F**	**P**	**significance**
Shore distances: 20m Error	 1 28	 9.07 1.29	 7.05	 0.013	 S
30m Error	1 28	45.14 1.71	26.42	0.001	S
40m Error	1 6	0.02 44.28	0.01	0.908	NS

In summer, the condition index at Cemetery beach was slightly higher than Corsair Bay at the 20 m distance, but Corsair Bay had a relatively higher index at both the 30 m and 40m. These differences were relatively small (Figure 2.5). The 2 way ANOVA (Table 2.7) showed that condition index was highly significant between the shore distances (P = 0.001), but not between reserve and non-reserve sites.

Table 2.6: Result of 1 way ANOVA for pipi condition index at the 20m, 30m and 40m shore distances at Cemetery beach (reserve) and Corsair Bay (non-reserve) during the summer December 2011 survey.

Source of variation	**df**	**MS**	**F**	**P**	**significance**
Shore distances: 20m Error	 1 28	 0.16 1.83	 0.09	 0.769	 NS
30m Error	1 28	0.481 0.927	0.52	0.477	NS
40m Error	1 28	7.30 2.14	3.41	0.076	NS

Table 2.7: Result of 2 way ANOVA for pipi condition index at 20m, 30m and 40m shore distances at Cemetery beach (reserve) and Corsair Bay (non-reserve) during during winter August 2011 and summer December 2011. Significant differences are shown in bold (P> 0.05)

Source of variation	df	MS	F	P	significance
Winter:					
Shore distances	2	216.861	142.14	0.001	S
Reserve & non-reserve sites	1	30.625	20.07	0.001	S
Interaction	2	11.806	7.74	0.001	S
Error	84	1.526			
Summer:					
Shore distances	2	163.097	99.84	0.001	S
Reserve & non-reserve sites	1	2.988	1.83	0.180	NS
Interaction	2	2.478	1.52	0.225	NS
Error	84	1.634			

2.9.5 Adult (harvestable size) and Juveniles

At Cemetery beach, the proportion of juveniles in the population were slightly higher than adults in both the winter and summer surveys (Figure 2.6). Juvenile pipi were 16% and 8% higher than adult in winter and summer respectively (Figure 2.6). At the non-reserve site at Corsair Bay juveniles (<40mm in shell length) dominated the population (Figure 2.6). The percentage of adult pipi also represents the percentage of harvestable size as mentioned earlier in the method section. The percentage of adult or harvestable size pipi increased in summer at both reserve and non-reserve sites. The increase at Corsair Bay was slightly higher than at Cemetery beach.

Chi- Square Goodness of fit test testing for a 50% ratio of adults and juveniles indicated that the difference between the expected and observed values of juvenile and adult at Cemetery beach were not significant ($P > 0.05$) in both the winter and summer surveys. In contrast at Corsair Bay, the differences were statistically highly significant ($P < 0.01$). There were 83% juvenile and 17% adult in winter and 72% juvenile and 28% adult in summer.

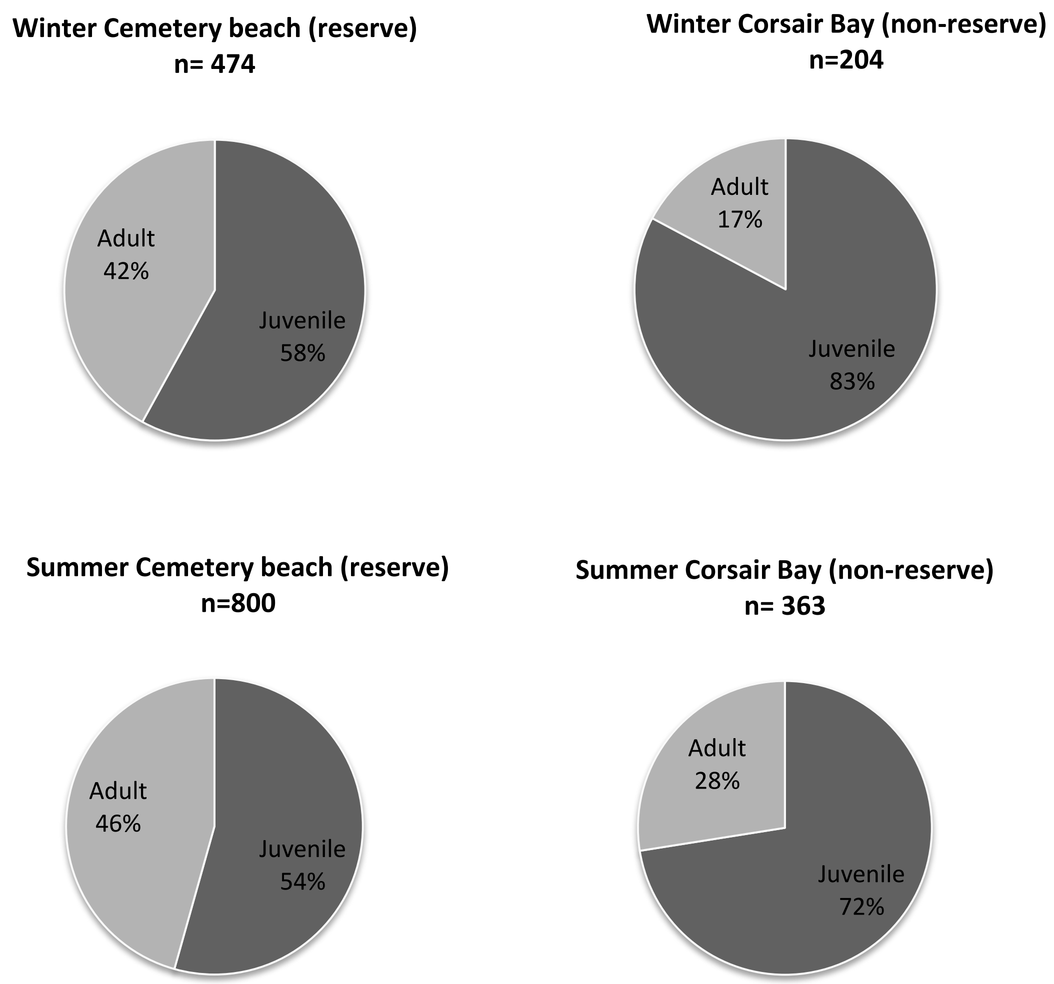


Figure 2.6: Percentage of juvenile and adult population at the Cemetery beach (reserve) and at Corsair Bay (non-reserve) during the main surveys during winter August 2011 and summer December 2011. * Adult percentage also indicates the harvestable percentage.

2.10 Discussion

One of the aims of the Rāpaki mātaitai reserve is to ensure the sustainability of the fisheries resources and its environment. Very little research has been done to identify the status of pipi in the reserve in the last fourteen years of its existence. Information on population size structure, density and distribution is critical for understanding the life history of marine invertebrate such as shellfish. The lack of observed data on many species of clam prevents successful management and hinders the formulation of predictions of how the population will react either to environmental changes or to the impact of commercial, recreational harvest and customary harvest.

2.10.1 Abundance and Density

At the 20-30 m from the top of the shore Corsair Bay had similar abundances of pipi to Cemetery beach. At the 40 m shore distance, Cemetery beach had significantly more pipi per core than Corsair Bay. Pipi abundance decreased at the lower 40 m shore at Corsair Bay and individuals were not found at the 50 m mark down the shore. The present study found that the subtidal lower shore of Corsair Bay is made up of silt/clay sediment. There have been several studies researching the process of sedimentation in Lyttelton Harbour (Curtis, 1995; Hart, 2004; Goff, 2005 and Hart, et al. 2008). All these studies have identified that sediment has increased due to the change in land use in the harbour catchment through deforestation, conversion to pasture and more recently residential development. According to Hart, et al. (2008) high concentrations of clay (>50%) were found in the northern areas of the upper Lytteton Harbour including Rāpaki, Cass and Corsair Bay. The guardians (kaitiaki) of Rāpaki mātaitai believe that increased sedimentation has affected the health of their fisheries, especially shellfish (Waddle, 1998).

Previous studies have shown that adult pipi were highly vulnerable to sedimentation and suspended sediment concentrations (Hewitt, et al. 2001). Cummings, et al. (2002) in a study at Waitemata Harbour concluded that pipi could be considered to be sensitive to increases in sediment and mud content. The absence of pipi at 50 m at Corsair Bay may therefore, be explained by the presence of silt /clay sediment. The difference in sediment characteristics is extensively used to describe the differences in the distribution and abundances of soft sediment fauna (Matthews, 2006). Species richness is often affected by differences in sediment particle size; areas with high percentages of silt/clay have fewer species in low numbers compared with areas of high percentages of sand (Yates, 1993).

In contrast to Corsair Bay, pipi aggregate at the 50 m down shore distance at Cemetery beach. This is the site of pipi beds and is also the harvesting zone. The highest density of pipi 4968 m^2 was found in this zone. This is comparable to the highest recorded density (4950 m^2) found by Hooker (1995) in the shallow subtidal area of Whagateau Harbour. At this density pipi were three to four deep digging through other pipi to gain a foot- hold in the substratum (Hooker, 1995).

The present study found a significant change in abundance between winter and summer at Cemetery beach (reserve) as well as Corsair Bay (non-reserve) sites. Both sites recorded a significant increase in abundance in summer. There has been very little study done to identify if there are any seasonal differences in the abundance of shellfish in New Zealand. However surf clam populations appear subject to huge periodic natural fluctuations in abundance, most likely due to high variable levels of recruitment and mortality (Loesch 1957; McLusky, et al 1975; Leber 1982; McLachlan, et al 1996). Lewis (1978) mentioned that recruitment variability could help interpret abundance patterns of intertidal benthos. This study found an increase in abundance of juveniles (< 25 mm) population in summer at both Cemetery beach and Corsair Bay which may be attributed to recruitment.

2.10.2 The Size Distribution of Pipi

Hooker (1995) found that pipi in Whangateau Harbour had distinct habitat segregation based on size and age. Juvenile pipi occurred high on intertidal shores, whereas fully mature adults (> 40 mm in shell length) were found at high densities (up to 4400 m^2) in sub-tidal beds in the main harbour channels. Intermediate sizes were found between these habitats. Grace (1972) also found that juvenile pipi were largely restricted to the 20 m shore distance from the top of the shore where there was coarse sediments. Jones (1983) suggested that juvenile pipi migrate very gradually down shore as they grow.

In the present study juvenile pipi occurred at the intertidal zones of the beach (10-30 m shore distance) at both Cemetery beach and non-reserve site at Corsair Bay. Very few adults (> 40 mm) were found exposed at low tide at Cemetery beach as well as Corsair Bay. There was a clear indication that pipi of different sizes occupied defined shore zones between high and low water mark. These observed patterns agree with and Grace (1972) and Hooker (1995) findings. The high number of juvenile pipi in the intertidal areas may be due to lower predation, probably from paddle crabs (*Ovalipes catharus*) and starfish (*Coscinasterias calamaria*) compared to predation in the subtidal zones (Hooker, 1995). Both paddle crabs and starfish were found in the subtidal areas of Cemetery beach.

2.10.3 Shell Lengths

The mean shell lengths of pipi at the non-reserve site at Corsair Bay were generally larger than the reserve site at Cemetery beach at the shore distances 20-40 m. Pipi at Cemetery beach were generally smaller but more abundant than at Corsair Bay. At the 40 m shore distance, pipi mean shell length at Corsair Bay was significantly higher than Cemetery beach in almost the entire survey period. These significant differences may be attributed to the different slope level of the two beaches. At Corsair Bay, 40 m from the top shore would be in the subtidal zone while at Cemetery beach would be still in the lower intertidal zone. Subtidal pipi may grow faster than intertidal pipi due to further increased submergence times and availability of food (Hooker, 1995). *Austrovenus stutchburyi*, for example, have been reported to grow significantly faster at low tidal heights compared to high levels (Walker and Heffernan 1990). Other studies from different parts of the world have confirmed these findings (Guevara & Neil 1989, Roseberry, et al 1991, De Mountaudoin 1996, Cardoso, et al 2007).

Pipi can reach a maximum size of about 80 mm in length (Creese, 1988). Pipi from the Whagateau Harbour rarely grew above 70 mm shell length (Hooker and Creese, 1995c). In Whangarei Harbour pipi over 75 mm were common (Dickie, 1986b; Haddon, 1989). In the present study, the maximum size of pipi collected was 64 mm from Cemetery beach. Most of the adult pipi were found at Cemetery beach, and most of these would be in the range of 45 – 64 mm. It is yet to be established why there were no pipi greater than 65 mm collected at Cemetery beach. It could be due to harvesting or environment conditions do not allow them to grow as big as they are found in the North Island. Pipi had different shell morphologies at different sites within the harbour and population size structure differed among sites (Hooker, 1995). The growth of the hard clam *Mercenaria* has been extensively studied throughout its wide geographic range, with growth rates in warmer waters typically faster than cooler waters (Jones, et al. 1990). Study of butter clam *Saxidomus gigantea* from Alaskan waters, reported that growth to a harvestable size was slightly longer than that reported from lower altitudes in British Columbia (Paul, et al. 1976). The differences in water temperature between the North

Island and South Island may explain the size differences of pipi at Rāpaki and Whangarei Harbour.

2.10.4 Size Structure

The population size structure of pipi at Cemetery beach and Corsair Bay were similar. They both displayed a bimodal structure, but this was more obvious at Cemetery beach than Corsair Bay in both winter and summer. According to Hooker (1995) the presence of bimodal pattern suggests there is good recruitment. In the present study there were many juveniles (< 15 mm) at both sites in winter which indicated recruitment at both sites. The first mode in a bimodal length – frequency distribution would arise due to the ongoing recruitment in the environment accompanied by a high mortality of small individuals with the second mode resulting from the process in which mortality decreases with increasing size (Shelmerdine, et al. 2006). In the present study, there were clear modes of juvenile pipi in winter and summer and a second mode of adult with relatively few intermediate sizes at both sites. A study of toheroa population carried out at Bluecliffs beach also found similar results where there was relatively little intermediate size toheroa (Beentjes, 2009). The more likely explanation for the low numbers of sub-adults is that mortality of juveniles was high and that relatively few pipi survive through to the sub-adult size range.

2.10.5 Adult (harvestable size) and Juveniles

The ratio of juveniles and adults between Cemetery beach and Corsair Bay was very different. The ratio of juvenile and adult pipi population at Cemetery beach was relatively similar, with an average of 44% adult and 56% juvenile in both the preliminary and main surveys. At Corsair Bay on the other hand, the population was heavily dominated by juveniles, with an average of 5% adults and 95% juveniles during the preliminary surveys and 22% adults and 78% juveniles in the main surveys. The presence of silt/clay at the subtidal zone at Corsair Bay may explain the lack of adult size pipi, but further studies need to be carried out to determine if suspended sediments are affecting the low adult population.

Other studies have found similar ratio of adults and juveniles for bivalves for example, Walker and Babcock (2001) found that the pipi populations in Torbay and Browns Bay were heavily dominated by juveniles with a mean size of 5 mm shell length. The main population modes for Torbay and Browns Bay *P. australis* were 1-11 and 2-6 mm shell length, respectively. Very few large adults were recorded. For the tuatua, *Paphies subtriangulata* sampled at Torbay in March 2001 (Walker and Babcock, 2001) were again heavily dominated by juvenile size classes with a modal size of 2-9 mm in shell length.

Cummings et al. (2003) suggest that lack of individuals of spawning size means recruitment at these sites will rely on immigration of larval and juvenile stages from outside the sites. According to Hooker (1995) the juveniles of many species have different distribution patterns from the adults, and recruitment to the adult populations in these species may be totally unrelated to their reproduction and settlement patterns (Sale, 1990). Recruitment at Corsair Bay could be helped by immigration of larval and juvenile stages from outside sites.

There is no minimum legal harvestable size for pipi in New Zealand but a survey carried out in the Auckland metropolitan area by Hartill and Cryer (1999) found that pipi with a mean length of 39.6 mm were harvested by non-commercial harvesters. The present study found that large adult pipi of harvestable size (> 40 mm) were significantly more abundant in the reserve site at Cemetery beach than the non-reserve site at Corsair Bay. Most of these adult pipi (> 40 mm) were found in the 50 m shore distance at Cemetery beach. The existence of large individuals in a population at no take reserve sites with less at non-reserve sites is probably due to the exclusion of fishing from the reserves (Davidson, et al. 2007). However, at Rāpaki mātaitai reserve, customary harvesting is allowed therefore, it is inappropriate to associate the higher percentage harvestable individuals to the exclusion of harvesting. The present study suggests that the higher percentage of harvestable pipi at Cemetery beach may indicate that the level of customary harvesting is sustainable. It is interesting to note the percentage of harvestable pipi at both Cemetery beach and Corsair Bay had increased in summer which suggests that harvesting has not affected the population structure. The customary harvest data were not available for the present study, the data would be important in identifying the sustainable level of customary harvest.

Natural populations generally show a broad distribution of age classes, however, this can be affected by a number of factors. Human harvest is generally size selective, and populations subject to harvest pressure tend to show a decline in the number of larger animals. A survey of non-commercial harvesters at 13 soft shore habitats in the Auckland region was carried out by the Ministry of Fisheries (Hartill and Cryer, 1999), they found that pipi were one of the popular species targeted by non-commercial harvesters. During my study, there were two occasions where harvesters were sighted at Corsair Bay, but the lack of recreational harvest data makes it difficult to associate the low number of adult pipi to harvesters. The present study suggests that the low numbers of harvestable pipi size at Corsair Bay may be related to the presence of silt /clay at the subtidal zones.

2.10.6 Condition Index

Condition index of bivalves have been reported to decrease with increasing age and size (Wenne and Styczynska – Jurewicz 1985; Bawazir, 2000). With increasing length there is a relative decrease in the shell contents (whole weight minus shell weight) and shell water (shell contents weight minus wet meat weight) components (Hickman and Illingworth 1980). The condition index of pipi in the present study showed that the smaller pipi which occupy the upper 20 m shore distance of the beach have a higher condition index than larger pipi that occupy the lower part of the beach. These patterns were observed at both Cemetery beach and Corsair Bay. Previous pipi studies have shown variation in condition index especially during spawning seasons. Booth (1983) results showed pipi in the northeastern of North Island had high condition index from February to May and declined during May and June maybe signifying spawning. Condition indices of toheroa have normally revealed an increase over autumn and winter, reaching the highest in late winter and early spring, and then decreasing (corresponding to spawning) to a minimum in late summer (Redfearn, 1974). According to Hooker and Creese (1995c), pipi do not have a discreet spawning period but a drawn out breeding period from late winter to late summer with spawning activity mostly occurring in spring.

The result of the present study indicated that there was some seasonal variation in the condition index of adult pipi greater than 40 mm which may be related to spawning. The condition index of adult pipi found at the 40 m shore distance during the preliminary survey was highest in autumn at both reserve and non-reserve sites. During the main survey the summer condition index at both reserve and non-reserve sites were higher than winter. There were many juveniles (< 5 mm) recorded at both sites in winter indicating spawning (Figure 2.4). The high condition index in autumn signifies the period just before spawning and decreased in winter due to spawning and increase again in summer after the spawning. Hooker (1995) found the pipi at Whangateau Harbour had high condition index over the autumn and early winter months then decreased from late winter to spring during spawning.

At the 20-30 m shore distances the condition index of pipi at Cemetery beach was generally higher than Corsair Bay. At 40 m Corsair Bay had a higher condition index during both the preliminary and main surveys. These differences could be due to the variation in environment conditions of the two sites. At Corsair Bay the 40 m shore distance would be subtidal while at Cemetery beach it would be still in the lower inter-tidal area. These differences would be due to the slope of the beach where Rāpaki has a gradual slope compared to Corsair Bay.

According to Seed (1968) and Hickman (1979) both growth rate and condition index improved following the transfer of intertidal mussels to subtidal levels. Subtidal pipi may have higher condition index than intertidal pipi due to further increased feeding at submergence times (Hooker, 1995). The present study suggest that submergence time was probably responsible for the observed difference in higher condition index at 40 m shore distance at Corsair Bay compared to Cemetery beach.

2.11 Conclusion

The present study found that the pupil population in the mātaitai reserve was different from the non-reserve site at Corsair Bay. Pipi were significantly more abundant in Cemetery beach reserve than Corsair Bay. At the lower intertidal and subtidal zone pipi at Cemetery beach were more densely populated and significantly had more adult harvestable size than Corsair Bay. The lack of adult harvestable size at Corsair Bay may be due to environmental conditions rather than harvesting. There were no recreational data to indicate that pipi was harvested at Corsair Bay. The higher percentage of adult harvestable pipi size at Cemetery beach suggests that customary harvest may be sustainable. The sustainability of customary harvest can only be proven if pipi population are monitored annually and compared to annual harvest.

Chapter 3: Evaluation of *Austrovenus stutchburyi* at Port Levy Mātaitai reserve and non-reserve sites on Bank Peninsula.

3.1 Introduction

Over the past 10 years, there have been shellfish bed losses in many parts of the world. The abundance of shellfish in many coastal areas of New Zealand has declined over the years (Grant and Hay, 2003, Hauraki Maori Trust Board, 2003) and few studies have determined which environmental factors have influenced the abundance, growth and population structure. The declined in cockle beds has prompted Māori communities to protect shellfish beds in their customary fisheries. The closure of shellfish beds however, has not always been successful in regenerating cockle populations. A decline in cockle density in Cheltenhem beach near Auckland, for example, prompted local iwi to establish a (rāhui) harvesting ban. After seventeen years, the cockle population still has not recovered (Hauraki Gulf Forum, 2011). The cockle beds in Port Levy (Koukourārata) have been closed for harvesting since 1995 by the local Māori community (Marsden, 2005). This present study tries to evaluate the effectiveness of the management of the harvest of cockles in Port Levy Matāitai Reserve. There have been no similar studies undertaken anywhere in New Zealand.

3.2 Study Objectives

The main objective is to evaluate the current status of cockle populations in two reserve sites at Port Levy (Pa village and Fernlea) and compare them with two similar non-reserve sites (Purau Bay and Charteris Bay). The harvest of cockles in the mātaitai reserve are only allowed on Saturday and Sunday during the month of September each year. A person can only collect 12 cockles on these two days. The study will specifically evaluate and compare the abundance, size structure, shell length and condition index of cockles within the reserves at Port Levy and corresponding non-reserve sites at Purau Bay and Charteris Bay.

3.3 Study species: Cockle, *Austrovenus stutchburyi*

The cockle *Austrovenus stutchburyi* is found throughout New Zealand including the South, North, Stewart and the Chatham Islands (Powell, 1979). *Austrovenus stutchburyi* normally lives in lower inter-tidal mud or sand flats of sheltered estuarine areas (Morton and Miller, 1973). Cockles occur from the high water neap mark to subtidal depths of 6-8 m and the upper distribution limit of cockles may be restricted by a minimum submergence time of 3.5 hours of per tide (Larcombe, 1971). Cockles of sizes greater than 35mm are generally found in areas covered for more than eight hours per tide (Belton, 1986). The population structure of cockle beds in New Zealand varies within bays and harbours (Bolton- Richie, 2005)**.** The duration of tidal cover and distance from the open sea have been found to be the main factors affecting the distribution of *A. stutchburyi*, but substrate type, salinity, wind and tide effects, wave action as well as predation are all significant factors (Larcombe, 1971).

A.stutchburyi is often a dominant species and densities as high as 4500/m² have been reported from some areas (Keith, 2011). Suspension feeders such as cockles tend to be more abundant in sediments with a larger grain size. The stability of the substrate is a significant factor in *A. stutchburyi* survival, because mature cockles are often buried and do not move around much (Belton, 1986).

The sexes are separate and maturity seems to be associated with size rather than age. Individuals greater than 18mm shell length are usually sexually mature and produce gonad during the spring and summer and spawn from summer to autumn (Larcombe,1971). Cockles are broadcast spawners, releasing their eggs and sperm into the water and fertilisation is subject to chance. Larvae can swim in the water for about 15-20 days before settling (Stephenson and Chanley, 1979).

Inter-annual recruitment of cockles varies significantly and juveniles and smaller animals are known to move extensively, but individuals greater than 25mm shell length remained basically sessile, moving only in response to disturbance (Keith, 2011). Growth rate and maximum age are extremely variable and very much affected by environmental factors. For example, populations 20 years old with shell lengths more than 60 mm have been recorded in the Avon – Heathcote estuary in Christchurch (Stephenson, 1981). Growth of individual cockles differs with size, season, year, and location. Small cockles grow faster than large cockles with the fastest growth occurring during spring and summer. Growth slows down significantly once the shell height reaches 40 mm (Kearney, 1999). In addition, growth is slower in the higher tidal ranges where cockles are covered for much shorter periods than in the lower tide ranges, reducing their opportunity to feed (Dobbinson, et al, 1989).

3.4 Methodology

Preliminary surveys were carried out to determine if there were seasonal variations in the abundance, distribution and size of cockles on the upper and middle shores. Preliminary surveys were carried out in spring October 2010, summer December 2010 and autumn April 2011. During the preliminary surveys a 5m x 20 m transect was used to sample the intertidal area. During the preliminary surveys, the cockle population at Pa village reserve site was compared to Cass Bay (non-reserve). Cass Bay is a soft sediment site, no corresponding gravel site was found during the preliminary surveys. The results of the preliminary surveys were variable and indicated that abundance of large cockles increased towards the lower shore. The survey design was therefore, changed during the main survey to investigate the density of harvestable cockles in the lower shore.

In the main survey, two customary harvesting sites within the Mātaitai reserve, Pa village and Fernlea were chosen as study sites and compared with two similar non-reserve sites at Purau Bay and Charteris Bay respectively. According to Jones, et al. (1993) and Rowley (1994) previous studies within marine reserves have been confusing because they only compared a single protected location with a non-protected control leading to the possibility that the observed differences were due to variability from location to location rather than protection effects. The two non-reserve sites were chosen based on both the presence of cockles as well as having a gravel intertidal area similar to their corresponding reserve sites.

The surveys were timed to coincide with several days of spring tides, allowing the maximum possible extent of the inter tidal beach to be surveyed at low tide**.** In the main survey the sampling was concentrated at the lower shore of each site. This was done to capture (evaluate) the abundance of the harvestable size cockles at each site and its variation during winter and summer, where summer is the more popular harvesting season. For the main survey, a 20m line transect (measuring tape) was positioned parallel to the tide line along the lower shore to record the densities of cockles. The 20 m line transect was used to ensure that the samples were collected from the lower shore where customary shellfish beds are located. Randomly generated distances were used to determine the site of the sampling at every 2m along the transect. This was done before the sampling to avoid any bias in determining the site. The samples were randomly collected using a (0.1m^2 metal quadrat). Ten quadrats were used to sample the number of cockles at each site and replicated until 100 plus cockles were collected. All cockles found within each quadrat were removed, counted and the shell lengths measured to the nearest 0.1 mm. After this, all the cockles were returned to their original position on the shore.

The condition index of cockles at two sites within Port Levy reserve were measured and compared to condition index of similar sites out of the reserve at Purau Bay and Charteris Bay. Condition index was determined as a proxy of organism health, and to compare the health of the bivalves among sites and over time (Davenport and Chen, 1987). The method used for calculating the condition index of cockles was the same as the method used for pipi described in Chapter 2.

A total of 15 cockles from each site measuring 15-40 mm were chosen to measure condition index. Measurements made on each individual cockle includes total weight (0.01g), total length (nearest 0.05 mm) and wet shell weight (nearest 0.01 g). Cockles were opened, and the meat removed and wrapped in aluminium foil. The wrapped tissue and the wet shell were then dried at 60˚C for 48hrs in an oven. The condition index of cockles (C.I.) was calculated as the ratio of the dry weight of the flesh /dry weight of shell x 100 (Walne, 1976). In this study, condition index was used to compare the health of cockles in customary reserves to similar sites outside the reserves.

3.5 Statistical Analysis

All analyses were performed using MINITAB 16 statistical software. One way Analysis of Variance (ANOVA) was used to compare the variation between reserve and control sites in terms of density**,** length and condition index. Significant differences ($P < 0.05$) between sites were further analysed by Tukey honest significant difference (HSD) test.

3.6 Preliminary Survey Results

Abundance

The mean abundance of cockles at Cass Bay (non-reserve) was greater than Pa village during all the preliminary surveys (Appendix 2: Figure B 2.1). The difference was statistically significant in spring and summer (Appendix 2: Table B 2.1). There were no significant seasonal differences in mean abundance at both Pa village and Cass Bay ($P < 0.05$) (Appendix 2: Table B 2.2).

Mean Shell Length

The cockle mean shell length at Pa village was greater than Cass Bay in spring and summer (Appendix 2: Figure B 2.2). The difference was statistically significant in spring ($P < 0.05$) (Appendix 2:Table B 2.3). In autumn, the mean shell length at Cass Bay was significantly greater than Pa village (Appendix 2:Table B 2.3). There were significant seasonal differences in mean shell at the Pa village ($P < 0.05$) (Appendix 2: Table B 2.4).

Size Structure

During the preliminary surveys there were juvenile cockles of size classes 5-14.9 mm at Pa village while Cass Bay had none (Appendix 2: Figure B 2.3). Cass Bay had a unimodal size class during the entire preliminary surveys, while at Pa village it was evident that in summer and autumn a bimodal size structure had developed. (Appendix 2: Figure B 2.3). There was no statistical significant difference in size class frequency between the two sites ($P > 0.05$).

3.7 Main Survey Results

3.7.1 Abundance and Density

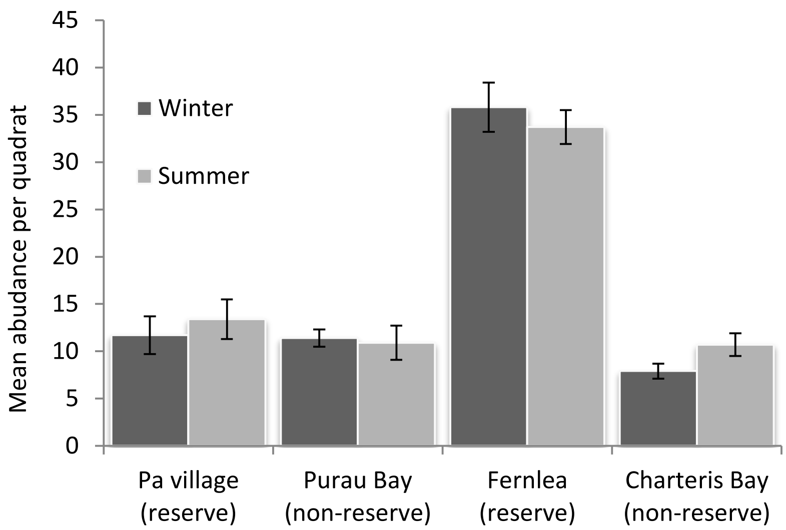


Figure 3.1: Cockle mean abundance per quadrat (± s.e) collected from pair 1: Pa village winter n=117 summer n=134 and Purau Bay winter n=114 summer n=109 and pair 2: Fernlea winter n=358 summer n=337 and Charteris Bay winter n=111 summer n=107 during the main surveys in winter August 2011, summer December 2011

The mean abundance at Fernlea was significantly greater than Pa village, Purau Bay and Charteris Bay during both the winter and summer surveys (Turkey HSD post hoc test). The mean abundance at Pa village, Purau Bay and Charteris Bay were relatively similar in both seasons. (Figure 3.1).

In winter the mean abundance of cockles at the two reserve sites (Pa village & Fernlea) was higher than the two corresponding non-reserve sites (Purau Bay & Charteris Bay) (Figure 3.1). While the mean abundance at Pa village was similar to Purau Bay 11.7 per quadrat compared to 11.4, Fernlea mean abundance was significantly higher than Charteris Bay 35.8 per quadrat in contrast to 7.9 ($P < 0.05$) (Table 3.1). Similarly in summer, the mean abundance at the reserve sites was higher compared to the non-reserve sites. The mean abundance at Pa village was 13.4 per quadrat compared to 10.9 at Purau Bay. At Fernlea the mean abundance was 33.7 per quadrat compared to 10.7 at Charteris Bay, this difference was statistically significant ($P < 0.05$) (Table 3.1).

There were no significant seasonal variations in abundance within the two reserve sites as well as the non-reserve sites between winter and summer (Table 3.2). There were slight increases in abundance at Pa village and Charteris Bay in summer, in contrast Purau Bay and Fernlea had slight decreases (Figure 3.1).

The density of cockles at Pa village ranged from 1-24 per quadrat or 10-240 per m^2 compared to 7-16 per quadrat or 70-160 per m^2 at Purau Bay. A total of 221 cockles were sampled at Pa village compared to 223 at Purau Bay. At Fernlea the cockle density range from 24-51per quadrat or 240-510 per m^2 compared to 3-12 per quadrat or 30-120 per m^2 at Charteris Bay. A total of 695 cockles were sampled at Fernlea compared to 218 at Charteris Bay.

Table 3.1: Results of 1 way ANOVA for cockles comparing the mean abundance per quadrat between reserve and non-reserve sites. Pair 1: Pa village (reserve) and Purau Bay (non-reserve) and Pair 2: Fernlea (reserve) and Charteris Bay (non-reserve) for the main surveys in winter August 2011 and summer December 2011.

Source of variation	df	MS	F	P	significance
Pair 1					
Pa village and Purau Bay (winter)	1	0.4	0.02	0.897	NS
Error	18	26.0			
Pa village and Purau Bay (summer)	1	31.25	1.08	0.311	NS
Error	18	28.85			
Pair 2					
Fernlea and Charteris Bay (winter)	1	4531.4	144.37	0.001	S
Error	22	31.4			
Fernlea and Charteris Bay (summer)	1	2645.0	112.23	0.001	S
Error	18	23.6			

Table 3.2: Results of 1 way ANOVA for cockles comparing seasonal average abundance per quadrat within reserve and non-reserve sites for the main surveys in winter August 2011 and summer December 2011.

Source of variation	df	MS	F	P	significance
Season					
Pa village reserve (winter and summer)	1	8.4	0.18	0.673	NS
Error	18	46.0			
Purau Bay non-reserve (winter and summer)	1	1.3	0.06	0.814	NS
Error	18	22.0			
Fernlea reserve (winter and summer)	1	22.0	0.44	0.515	NS
Error	18	50.0			
Charteris Bay non-reserve (winter and summer)	1	44.80	4.58	0.064	NS
Error	22	9.77			

3.7.2 Shell Lengths

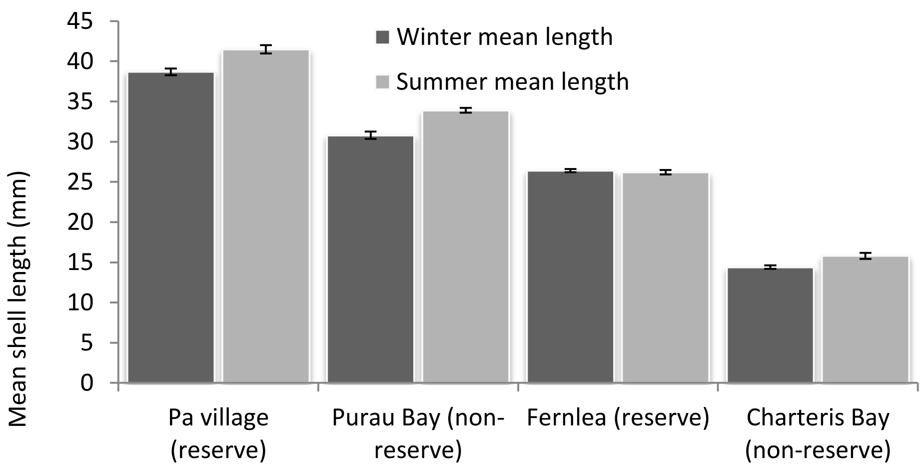


Figure 3.2: Winter and summer cockle mean length (± s.e.) at Pa village (reserve), Purau Bay (non-reserve), Fernlea (reserve) and Charteris Bay (non-reserve).

The mean cockle lengths at both reserve sites (Pa village and Fernlea) were significantly higher than the non-reserve sites (Purau Bay and Charteris Bay) during both surveys in winter and summer ($P < 0.05$) (Table 3.3). In winter the mean cockleshell length varied between sites and ranged from 38.7 mm at Pa village reserve to 14.4 mm at Charteris Bay (Figure 3.2). In summer the range was 41.5 mm at Pa village to 15.7 mm at Charteris Bay. Mean cockle length was significantly different seasonally in all sites except Fernlea (Table

3.4). The increase in adult cockles (> 20 mm) in summer at Pa village, Purau Bay and Charteris Bay contributed to the seasonal significant differences (Tukeys HSD post hoc test).

Table 3.3: Results of 1 way ANOVA for cockles comparing mean lengths in winter and summer between reserve and non-reserve sites.

Source of variation	df	MS	F	P	significance
Sites					
Pa village and Purau Bay (winter)	1	3502.4	167.24	0.001	S
Error	224	7.06			
Pa village and Purau (summer)	1	3097.1	167.72	0.001	S
Error	211	18.50			
Fernlea and Charteis Bay (winter)	1	1211.2	888.20	0.001	S
Error	468	13.60			
Fernlea and Charteis Bay (summer)	1	8880.8	408.59	0.001	S
Error	442	21.70			

Table 3.4: 1 way ANOVA results. Comparing seasonal variations in mean shell length of cockles at within reserve sites and non-reserve sites in winter August 2011 and summer and summer December 2011.

Source of variation	df	MS	F	P	significance
Seasonal mean size					
Pa village reserve (winter & summer)	1	444.7	18.58	0.001	S
Error	219	23.9			
Purau Bay non-reserve (winter & summer)	1	521.0	33.62	0.001	S
Error	216	15.5			
Fernlea reserve (winter & summer)	1	5.3	0.26	0.608	NS
Error	694	20.0			
Charteris Bay non-reserve (winter & summer)	1	94.24	9.71	0.002	S
Error	216	9.71			

3.7.3 Size Structure

Winter

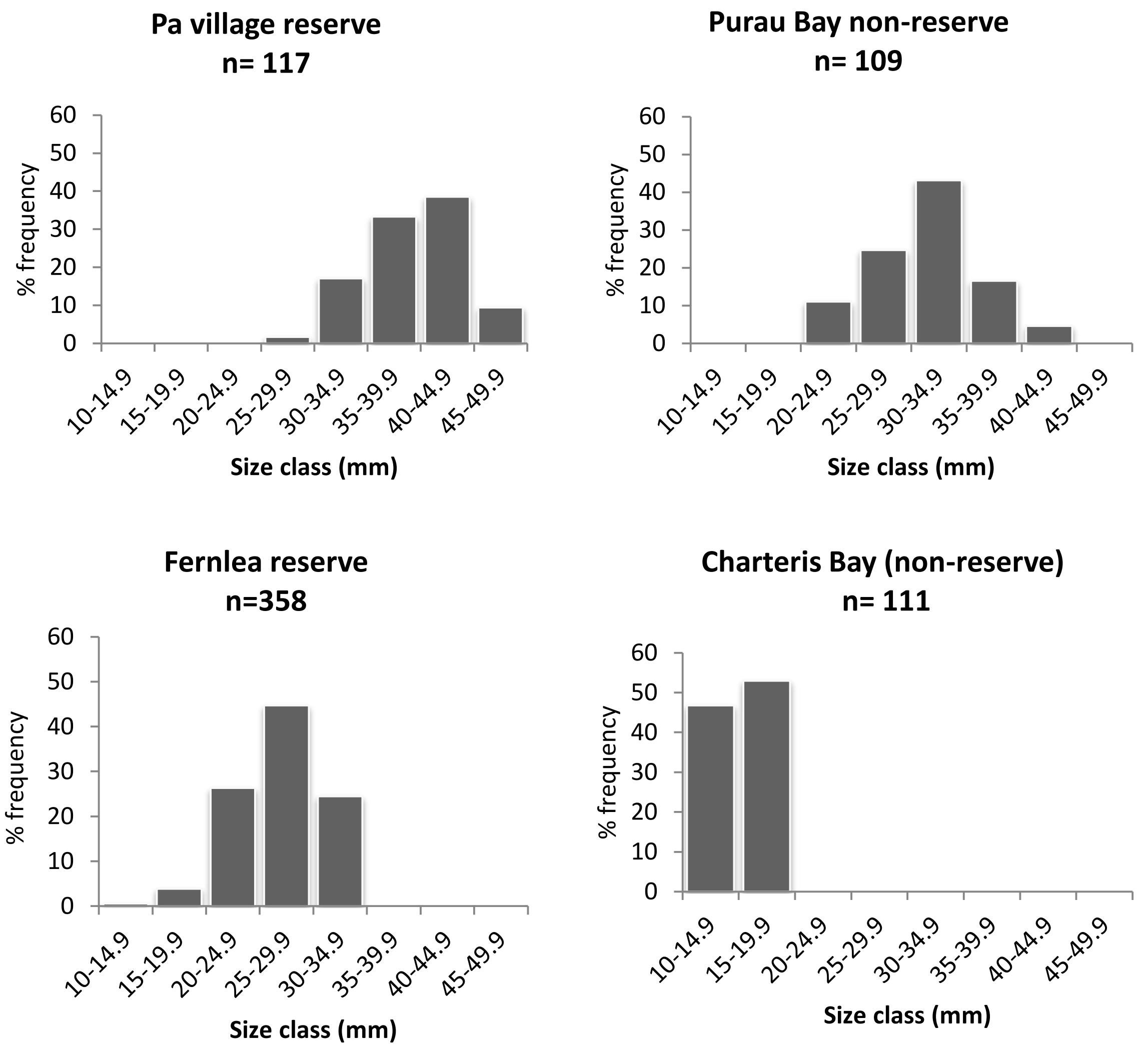


Figure 3.3 Size class frequencies of cockles at Pa village and Fernlea (reserve sites) and Purau Bay and Chateris Bay (non-reserve site) in winter August 2011

In winter the cockle size frequency distribution at all sites appeared unimodal but modal size classes varied between sites (Figure 3.3). The two reserve sites had higher modal size classes compared to non-reserve sites**.** The modal size class at Pa village was 40-44.9 mm, two size classes higher than Purau Bay (non-reserve) where the mode was 30-34.9 mm (Figure 3.3). At Fernlea the modal size class was 25-29.9 mm, one size class higher than Charteris Bay where the mode was 15-19.9 mm. The cockles size structure between Pa village and Purau Bay were generally similar compared to Fernlea and Charteris Bay where there were significant differences in size ranges. The length of cockles at Fernlea was smaller than Pa village and Purau Bay. The largest size class at Fernlea was 30-34.9 mm compared to 40-44.9 mm at Pa village and Purau Bay.

Sexual maturity is used in this thesis to define juveniles from adults. According to Larcombe (1971) cockles are sexually mature when they are 18-20 mm in shell length. In winter the population structure of cockles varied between the four sampling sites. The number of size classes varied from five at Pa village and Purau Bay to four at Fernlea and only two at Charteris Bay (Figure 3.3). Cockles at the two reserve sites had higher percentage of adults compared to non-reserve sites. Cockles sampled at Pa village and Purau Bay were exclusively adults (> 20 mm), in contrast Charteris Bay population were entirely juveniles (< 20 mm) (Figure 3.3. At Fernlea 96% of the population were adults (> 20 mm) (Figure 3.3)

Summer

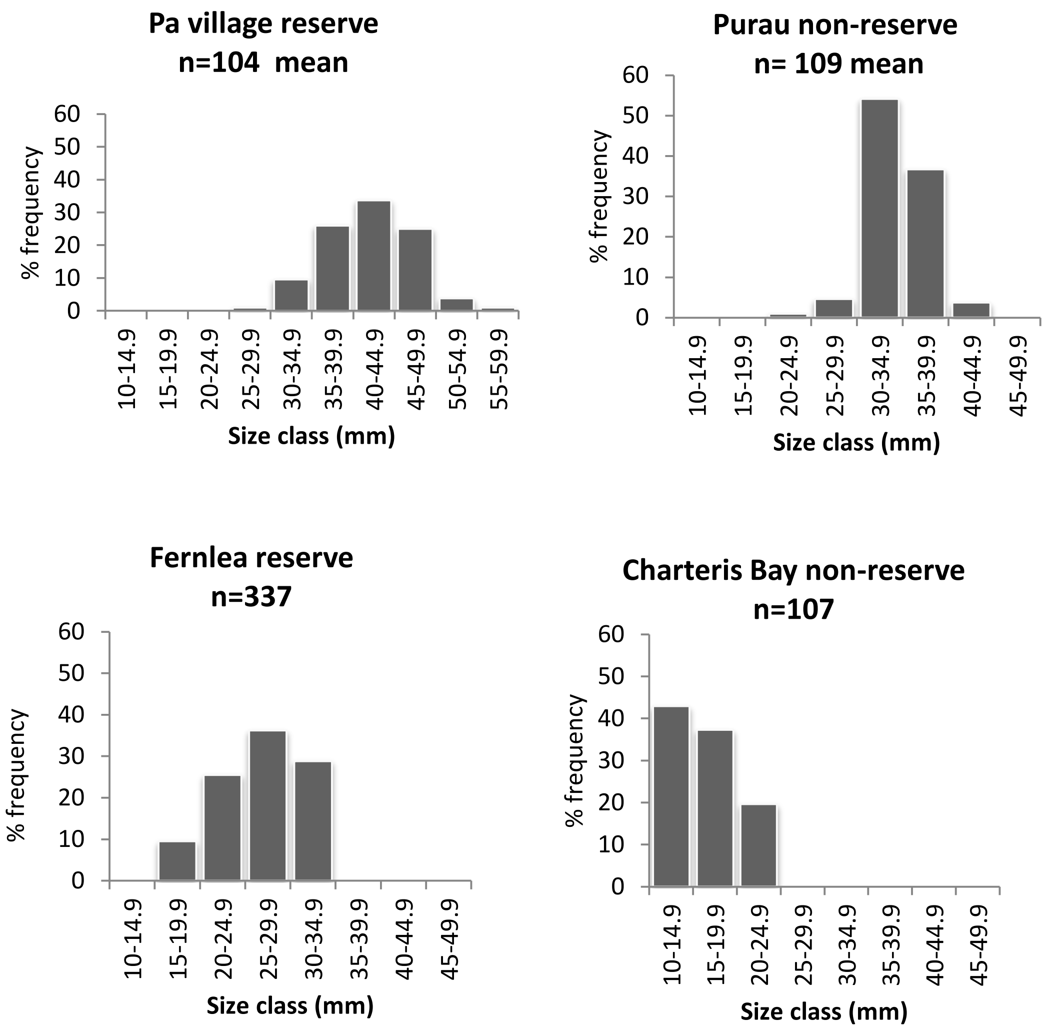


Figure 3.4 Size class frequencies of cockles at Pa village and Fernlea (reserve sites) and Purau Bay and Chateris Bay (non-reserve site) in summer December 2011.

Similar to winter all sampling sites had a unimodal size frequency distribution but modal size classes varied between sites (Figure 3.4). The two reserve sites again had higher modal size classes compared to non-reserve sites. The modal size class at Pa village and Purau Bay were the same as winter 40-44.9 mm and 30-34.9 mm respectively (Figure 3.4). At Fernlea the modal size class did not change remaining at 25-29.9 mm, but mode size class at Charteris Bay decreased from 15-19.9 to 10-14.9 mm. The number of size classes were the same as winter for all sites except for Charteris Bay which increased from two size classes to three (Figure 3.4). At Purau Bay the summer population size structure was clearly different from winter. About 91% of the summer population were between size ranges 30-39.9 mm compared to 59% in winter. Cockles at Fernlea did not have larger size classes (> 35 mm) found at Pa village and Purau Bay.

Pa village and Fernlea had higher percentage of adult population compared to non-reserve sites at Purau Bay and Charteris Bay. Pa village and Purau Bay summer size structure were very similar to winter. Both sites again did not include any juveniles. Charteris Bay population change slightly to record a 20% adult population and 80% juveniles (Figure 3.4). At Fernlea 90% of the cockle population sampled were adults and juveniles increased from 4% in winter to 10% in summer (Figure 3.4).

3.7.4 Harvestable Cockles

According to Hartill and Cryer (1990) cockles of shell length greater than 34 mm are harvested. In this study the percentage of adult and harvestable cockles varied between sites. Both Pa village and Purau Bay had no juvenile cockles (< 20 mm), the percentage of harvestable cockles (> 34 mm) in shell length between the two sites were significantly different. At Pa village about 94.2% of cockles were of harvestable size compared to 56% at Purau Bay (Table 3.5). At Fernlea about 9% of its population were juveniles (< 20 mm) in contrast cockles at Charteris Bay 80% of its population were juveniles. The percentage of harvestable cockles (> 34 mm) at Fernlea was 6.2% while Charteris Bay had no harvestable size cockles (Table 3.5). The percentage of harvestable cockles increased in summer at both reserve sites as well as at Purau Bay.

Table 3.5 Percentage of harvestable cockles at reserve sites at Pa village and Fernlea and non-reserve sites at Purau and Charteris Bay in winter August 2011and summer December 2011

Season	Sites	No. of harvestable cockles	% of harvestable cockles	Total cockle population
Winter	Pa village (reserve)	98	83.8	117
	Purau (non-reserve)	33	30.3	109
	Fernlea(reserve)	0	0	358
	Charteris Bay(non-reserve)	0	0	111
Summer	Pa village (reserve)	98	94.2	104
	Purau (non-reserve)	62	56	109
	Fernlea (reserve)	21	6.2	337
	Charteris Bay (non-reserve	0	0	107

3.7.5 Condition Index

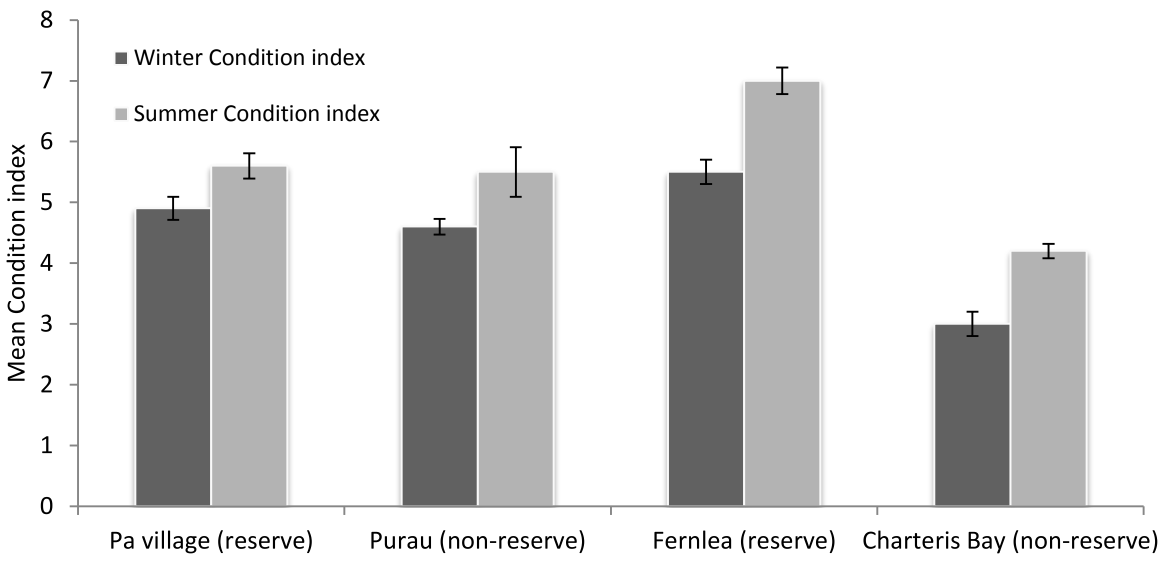


Figure 3.5: Seasonal comparison of mean condition index of cockles (± s.e) within reserve sites at Pa village and Fernlea and within non-reserve sites at Purau Bay and Charteris Bay during winter August 2011 and summer December 2011

The mean condition index of cockles in all samples ranged from between 3.0 at Charteris Bay to about 7.0 at Fernlea (Figure 3.5). The two reserve sites Pa village and Fernlea had higher condition index than the two corresponding non-reserve sites Purau Bay and Charteris Bay in both winter and summer (Figure 3.5). At Fernlea the condition index was significantly higher than Charteris Bay in both seasons ($P < 0.05$).

Fernlea had the highest condition index between the four sites in both winter and summer. The variation in condition index between the four sites in winter was highly significant ($P < 0.05$). Tukeys HSD post hoc test showed that the condition index at Fernlea was significantly greater and different from Purau Bay and Charteris Bay but similar to Pa village. The condition index of cockles at Charteris Bay on the other hand was significantly lower and different from all the other three sites.

Comparison of seasonal condition index for winter and summer revealed that the summer condition indices were higher than winter at all sites (Figure 3.5). The seasonal differences were statistically highly significant ($P < 0.\ 05$) at all sites (Table 3.6). The higher condition index at all sites in summer was the main contributor to the significant differences (Tukeys HSD post hoc test).

Table 3.6: 1 way ANOVA results comparing seasonal variation in condition index of cockles at within reserve sites (Pa village and Fernlea) and non-reserve sites (Purau Bay and Charteris Bay) between winter and summer.

Source of variation	df	MS	F	P	Significance
Seasonal condition index					
Pa village (winter & summer)	1	4.0	7.09	0.013	S
Error	28	0.57			
Purau Bay (winter & summer)	1	7.20	20.05	0.001	S
Error	28	0.36			
Fernlea (winter & summer)	1	17.76	23.08	0.001	S
Error	28	0.77			
Charteris Bay (winter & summer)	1	10.21	33.73	0.001	S
Error	28	0.30			

3.8 Discussion

In New Zealand cockle populations have been well documented in selected areas in the North Island from early studies by Larcombe (1971), Stephenson (1981) and Blackwell 1984), and more recently from studies undertaken by the Ministry of Fisheries. MFish has monitored the abundance and size of cockles at fourteen sites in the Hauraki Gulf since 1998 and found that the overall abundance has fluctuated overtime. In Whangateau Harbour there was a 36% reduction in overall abundance between 2004 and 2010 and in Umupuia the overall cockle populations declined between 1998 and 2007 and then increased between 2007 and 2010. There were statistical significant declines in the number of harvestable cockles (> 34 mm) recorded at the Whangateau Harbour and Umupuia sites between 2006 and 2009, but very little change occurred at Okoromai Bay on Whangapoua Peninsula (Pawley, 2011).

In Wellington, cockles at Pauatahanui Inlet in 2007 were half the density in 1976 and there has been an increase in large cockles at high and lower mid tide since 2004 (Michael, 2008). In the upper South Island the mean size of cockles at Ferry Point has declined since 1996, but the biomass of small cockles in Tapu Bay have increased since 2004 (Osborne, 2010). In the Canterbury region little is known about the cockle populations other than the population in the Avon- Heathcote estuary (Stephenson, 1981; Marsden and Pilkingston, 1995). The cockle population on Banks Peninsula are known to occur in mudflats but very little quantative data is available. Voller (2003) has done some studies in Port Levy since 1997 and found that population stocks were not increasing. The present findings of the cockle population at Port Levy are discussed below.

3.8.1 Cockle Abundance and Density

Densities of cockles can vary from a few individuals per square meters to thousands (Dabouineau, 2009). Wong and Thomson (1992) found a maximum density of 1925/m² near the mouth of the Avon-Heathcote Estuary, Stephenson (1981) recorded a maximum density of 2000/m² near the Heathcote River channel. In the present study the highest maximum cockle density of 510 per m² was found at Fernlea. This is similar to the density of 500 per m² recorded at Te Makutu Bay marine reserve on the South Coast of Waiheke Island.

According to (Stephenson, 1981) cockles can be subjected to many physical variables like substrate composition which affect their distribution and abundance. The present study suggests that the rocky substrates at Pa village and Fernlea as well as Purau Bay and

Charteris Bay may limit the space for settlement and growth of cockles compared to the soft silt and sandy substrate available at Avon-Heathcote Estuary. The significant difference in maximum densities between Fernlea and Avon Heathcote therefore could be due to the differences in the substrate between the two sites.

Environmental variables affect the community structure in the estuarine environment (Malloy, 2007) and the interactions between the density and size of bivalves is highly complex (Stewart, 2005). Cockle population abundance and densities are variable, even within the same shore (Stephenson, 1981). In the present study cockle abundance was higher at the reserve sites (Pa village and Fernlea) compared to non-reserve sites at Purau Bay and Charteris Bay, but the difference was only significant between Fernlea and Charteris Bay. At Fernlea abundance was significantly different and higher from all other three sites. Environment variables, such as food supply between Fernlea and the other three sites could have a role in the differences in abundance.

According to Grange (1993) densities of cockles increases towards the lower shore. The lower shore areas are covered by the tide for longer periods than high and upper mid tide areas, providing longer feeding opportunities, and therefore more energy for growth and survival (Michael, 2010). In the present study, comparison of results showed that the highest densities of cockles occurred lower on the shore at all study sites. At Fernlea the increased in density at the lower shore was significant.

3.8.2 Shell Lengths

Many factors are known to affect the growth rate of bivalves (Bayne, 1976). The major factors considered to affect growth include: body size, temperature, tidal level, emersion time, density, salinity and food availability (Seed and Brown, 1975; Broom, 1982). In the present study the mean cockle lengths at both reserve sites (Pa village and Fernlea) were significantly higher than the non-reserve sites (Purau Bay and Charteris Bay). The survey results indicated that the differences in mean shell length were associated with a higher presence of large adults in the reserve sites. Marine cockles have been found to have a high growth rate as well as a high tissue weight which cannot be attributed to the lesser density of cockles, but probably reflects a more favorable habitat (MacDonald and Thompson, 1985). Considering all the factors that affect the growth of cockles, higher food availability at the two reserve sites appears to be the most likely explanation for the higher mean shell length recorded at Pa village and Fernlea.

The present study showed significant seasonal variation in shell length at Pa village, Purau Bay and Charteris Bay. The present study showed that the adult population in summer was higher than winter which caused the seasonal differences. Very few studies have been done in New Zealand to verify seasonal variation in cockle shell lengths. Studies of cockle population in European countries have associated seasonal fluctuations with severe winters (Beukema, 1979; Strasser, 2000). According to Ramon (2003) a monthly sampling in the Wadden Sea found that adult cockle *Cerastoderma edule* (L) were found to be absent from the study site after a severe winter. After severe winters low densities of cockles were observed in lower intertidal areas where they had been abundant before (Kristensen, 1959; Hancock and Urquhart 1964). The winter survey in the present study was carried out after two days of snow in August 2011. The Port Levy Hills was still covered in snow when the winter sampling was done. After severe winters low densities of cockles were observed in lower intertidal areas where they had been abundant before (Kristensen, 1957; Hancock and Urquhart, 1964). The present study suggests that the seasonal fluctuations of the adult population could be due the severe conditions in winter.

3.8.3 Size Structure

The population structure of cockle beds in coastal New Zealand differs within bays and harbours (Bolton-Ritchie 2005). The present study confirms this for cockle population in Banks Peninsula. Pa village reserve and Purau Bay (non-reserve site) were dominated by adult cockles (> 20 mm). At Fernlea reserve adult cockles greater than 35 mm were missing while Charteris Bay cockle population were dominated by juveniles (< 20 mm). All four sites had unimodal size frequency distributions which seem to indicate that although there is recruitment each year into the population, it may be sporadic (Stewart, 2005).

Populations of cockles are highly variable with irregular recruitment success (Marsden and Adkins, 2009). The result of the present study showed a low presence of juvenile population during both the main and preliminary surveys. The absence of juveniles at Pa village and Purau Bay as well as its low presence at Fernlea during the main survey could be because the sampling was concentrated at the lower shores to capture large harvestable size cockles. The preliminary surveys though were carried out in the upper and middle shore where smaller size cockles would normally occur. The results indicated a low percentage of juvenile cockles at Pa village (spring 1.1%, summer 6.1% and autumn 9.2%). The lack of smaller size classes in the population structure therefore could be due to the low continuous recruitment at the site.

Human exploitation of intertidal organisms has been reported to be a very selective activity, targeting the largest individuals (Moreno et al. 1984, Lasiak and Dye, 1989). In the present study the two reserve sites showed a higher abundance of adult (> 20 mm) and harvestable cockles (> 34 mm) than their corresponding non-reserve sites. Pa village the main customary harvesting site, 89% of the cockle population surveyed in winter and summer were of harvestable size compared to about 40% at Purau Bay. Earlier studies of cockle population at Pa village had indicated the presence of large adult cockles. For example according to Marsden and Adtkins (2009) a survey of Port Levy cockles population in 2006 showed that Fernlea had a variable pattern of class sizes while Pa village site was dominated by large cockles. Voller (2006) in his research also suggested that the number of harvestable cockle at Pa village had increased.

The result of the present study showed that percentage of harvestable cockles increased at both the reserve sites and the non-reserve site at Purau Bay. This may reflect a low harvesting pressure at these sites. Harvesting of cockles at Port Levy reserve is only allowed in September where a gatherer is permitted to take 12 cockles per day. The higher percentage of harvestable cockles at the two reserve sites seems to indicate that the protection of the reserve is working but this can only be confirmed with continuous monitoring. The unavailability of customary harvest data also makes it difficult to explain the high percentage of harvestable cockles at Pa village. The high percentage (89%) of harvestable cockles recorded in the present study at Pa village were notably higher than the 36%, 17%, 10% and 7.4% harvestable size recorded in 2009 at Okoromai Bay, Lews Bay, Cockle Bay and Whangateau Harbour respectively in the North Island (Pawley, 2011).

Cockles in New Zealand depend on many factors, including temperature, salinity, food resources and shore level (Dobbinson et al. 1989; Stewart and Creese, 2002; Marsden, 2004). In a highly contaminated site in Tamaki in the North Island, Stewart (2005) found the maximal cockle shell length was below 25 mm. In the present study Charteris Bay cockles were significantly smaller than all other sites. There were only three size classes and cockles were all (< 25 mm) in shell length. Food availability and quality are known to affect the growth rate of shellfish (Newell and Hidu, 1982; Beukema et al. 2002). The availability and quality of food most probably limit the growth of cockles at Charteris Bay. At Fernlea cockles were smaller than Pa village and Purau Bay. The density of cockles at Fernlea was significantly higher than both of the above sites. In areas where cockles occur in high densities, competition for food may reduce growth (Michael, 2010; Broom, 1982). The present study suggests that higher cockle density at Fernlea was responsible for limited growth of cockles.

3.8.4 Condition Index

Condition indices are usually considered as useful measurements of the health of bivalves (Crosby and Gale, 1990) and are affected by various factors including food availability, temperature, salinity, and most importantly reproduction (Boscolo et al. 2003). Marsden and Pilkington (1995) found that variation in cockle condition index was related to both salinity and chlorophyll levels in the Avon Heathcote estuary.

In the present study the condition index of cockles from the reserve sites was higher than the non-reserve sites in both the winter and summer surveys. This study suggests that the higher condition index at the reserve sites are most probably due to the higher availability of food. Unless there is a high availability of phytoplankton, there could be insufficient food resources to maintain clam condition and promote tissue and shell growth (Marsden, 2004). Fernlea had the highest condition index compared to Pa village, Purau Bay and Charteris Bay. The high condition index at Fernlea may be related to high food availability due to its closeness to a creek which may provide phytoplankton (nutrients) to the water column.

The complex interactions of a variety of factors including food, temperature, and salinity on the metabolic activities of bivalves, mainly the growth and reproductive processes are known to cause seasonal changes in condition index of bivalves (Hickman and Illingworth, 1980).
In the present study there were significant seasonal differences in condition index between winter and summer. The summer condition index was significantly greater than winter at all sites. This result is similar to findings by Marsden (2004) at Avon Heathcote Estuary where condition index close to the oxidation ponds was significantly higher in December compared to other months. Phytoplankton levels largely increase in spring and summer, providing the energy which is essential for growth and reproduction in bivalves (Newell and Bayne, 1980). The effect of the temperature could be direct, affecting the metabolic rate, or indirect, affecting the availability of food (Taylor and Venn 1979, Park, et al. 2001). According to

Pilkington, (1992) and Marsden and Pilkington, (1995) chlorophyll levels at Avon Heathcote estuary closely coincide with the seasonal temperature profile where the highest values were recorded during December or January. Studies from other parts of the world also confirm the higher availability of chlorophyll in spring and summer (Hummel, et al. 2000b, Honkoop & Van der Meer, 1998 and Kingston, 1974). The seasonal difference in condition index is possibly due to increased temperature and gonad development.

The condition index of bivalves is known to be high just before spawning and then decreases during the main activity of spawning. In New Zealand cockles produce gonad during spring and early summer and spawn during late summer to autumn (Marsden, 2004). In this study the summer survey was carried out in early summer (December) corresponding to the period where cockles condition index is expected to be high. Clams retain low tissue body-weight over winter (June and July), then the weight increases rapidly as a result of body growth and gamete development in spring (Marsden, 2004). The seasonal differences in condition index are possibly due to increased temperature and gonad development. The seasonal differences in condition index found in this study are similar to findings of previous studies in New Zealand by (Larcombe 1971, Stephenson, 1981, Marsden & Pilkington 1995). Studies of cockles from other parts of the world also confirm similar findings (Chang, et al. 1982; Yang, et al. 2011).

3.9 Conclusion

In conclusion this study presents some evidence that the Port Levy customary reserve is providing refuge for more cockles to grow into adults and harvestable size as well as increasing cockle density. The Port Levy customary reserve therefore has the potential to improve the sustainability of the cockle population.

Chapter 4: Evaluation of *Turbo smaragdus* (cats eye) populations in reserve and non-reserve areas in Canterbury

4.1 Introduction

The phylum Mollusca is one of about twenty major groups of the animal kingdom (Cox, 1962). According to (Hickman and McLean, 1990) nearly 80% of molluscs are gastropods, but few gastropod superfamilies rival the marine Trochidae (Prosobranchia: Vetigastropoda) in numbers of genera, species and individuals. The Trochidae include the families Turbinidae, Skeneidae and Trochidae (Hickman and McLean, 1990). They are distributed worldwide, found at all latitudes and depths, ranging from intertidal to subtidal and with some in the bathyal zone (Joll, 1980; Worthington and Fairweather, 1989; Hickman and McLean, 1990). They are known to reach their maximum diversity in warm tropical and subtropical waters (Hickman and McLean, 1990).

Turbo (Lunella) smaragdus is one of the common species of the Turbinidae family found in New Zealand. Four other species of the Turbinidae family include *Turbo granosus*, *Cookia sulcata*, *Astraea heliotropium* and *Homalopoma fluctuata* (Walsby and Morton, 1982). *Turbo* is found in wide range of habitats, including rocky intertidal, subtidal and estuarine environments throughout New Zealand (Alfaro, 2006). It is one of the larger and more prominent grazing snails in the coastal areas of New Zealand**.** Its extensive distribution, ability to survive in a diversity of habitats as well as its large size (up to 50 mm in width) makes *Turbo* an important component of the rocky and soft shore environments.

Previous studies on *Turbo* have been done mostly in the North Island in the Auckland area. Smith (1969) investigated the abundance and distribution of *Turbo*. Beckett (1969) examined the relationship between movement and feeding ecology. In (1977) Walsby related the distribution of *Turbo* on the shore to growth and movement. The feeding ecology and the interactions of *Turbo* with other dominant grazers of the intertidal was investigated by Edwards (1982). *Turbo* breeding cycles, spawning seasons, stimulus and larval development were examined by Grange (1982).

Little has been published on *Turbo* in the South Island. It has been included in the description of the intertidal ecology of the Kaikōura Peninsula (Rasmussen, 1965; Marsden, 1981).

Robinson (1992) investigated the population and reproductive ecology of *Turbo* in the Kaikōura region.

4.2 Study Objectives

The objective of this chapter was to investigate the *Turbo* population in the three customary reserves in Kaikōura, Rāpaki and Port Levy (Koukourārata) and determine if they have benefited from customary management practices. The population of *Turbo* in Kaikōura have not been harvested since the establishment of the rahūi while in Rapaki and Port Levy the harvesting has been limited to local people and controled by permits. This research specifically measured *Turbo* abundance, population size structure and distribution comparing three customary reserves with non-reserve sites.

4.3 Methodology

Cats eye populations were investigated in three reserves in Kaikōura, Rāpaki and Port Levy. At Kaikōura cats eyes from one site within the reserve (Avoca Point) and one outside the reserve (Wairepo flats south) were compared in preliminary surveys. Sampling intensity was increased to two sites for the main survey. Avoca Point and Whakatu Point were sites within the reserve and Wairepo flats north and Lab rocks from non-reserve sites on the Kaikōura Peninsula. At Rāpaki *Turbo* populations from two sites within the reserve (Cemetery beach and Aunties beach) were compared to two Banks Penninsula non-reserve sites (Corsair Bay and Cass Bay south) during both the preliminary and main surveys. At Port Levy one site within the reserve (Pa village) and one site outside the reserve Cass Bay North were compared during the preliminary and main surveys**.** Only one site was compared in Port Levy because there was only one traditional site associated with traditional harvesting.

Preliminary surveys were carried out in spring 2010, summer 2011 and autumn 2011 to determine if there were seasonal variations in the abundance, distribution and size of *Turbo* on the upper and middle shores. A 5m x 20 m transect was used to sample the intertidal area. Twenty quadrats ($0.1m^2$) were used to sample the abundance and size distribution of the *Turbo* populations in the reserve and non-reserve sites. All *Turbo* found within each quadrat were counted and the shell lengths measured to the nearest 0.1 mm. After this, they were returned to their original position on the shore. The results of the preliminary survey showed that cats eye abundance and size increased towards the lower shore.

The main surveys were carried out in winter, August 2011 and summer, December 2011 and sampling was restricted to the lower shore. This was because *Turbo* of harvestable size were found in the lower shore and summer is the popular season for harvesting. A line transect was used to record the abundance of *Turbo* in the lower shore of reserve and non-reserve sites. At each site 20m line transect (measuring tape) was positioned along the lower shore to record the number of cats eyes. The survey comprised of 4 transects at each site. The samples were randomly collected every 2m using a $0.1m^2$ square metal quadrat. Randomly generated distances were used to position the sampling site every 2m along the transect. This was done before the sampling to avoid any bias in determining the site. Ten quadrats were sampled at each transect therefore 40 quadrats were sampled at each site. All cats eye found in each quadrat were measured to the nearest 1mm in length and returned to the substrate.

4.4 Statistical Analysis

All analyses were performed using MINITAB 16 statistical software. One and Two- way Analysis of Variance (ANOVAs) was used to compare the abundance and shell length of cats eyes in the reserve and non-reserve sites. Where there were significant differences ($P < 0.05$) these were further analysed by Tukey honest significant difference (HSD) test. Categorical variables like the ratio of juveniles and adults in the population were compared using Chi – Square Goodness of Fit tests. *Turbo* of shell length less than 25 mm were classified as juvenile while those greater than 25 mm were classified as adult.

4.5 Preliminary Survey Results

4.5.1 Abundance and Density

Kaikōura

At Kaikōura the mean abundance of *Turbo* at Avoca Point reserve was slightly higher than Wairepo flats (non-reserve) during all the preliminary surveys (Appendix 3: Figure C 3.1). There was very little seasonal variation in abundance at each site (Appendix 3: Table C 3.2)

Banks Peninsula

Rāpaki reserve

Cemetery beach reserve had a higher mean abundance than Corsair Bay non-reserve site in all preliminary surveys but the difference was not significant ($P > 0.05$) (Appendix 3: Table C. 3.3). There was no significant seasonal variation in abundance at both sites during the entire preliminary surveys (Appendix 3: Table C 3.4). The mean abundance of *Turbo* at Aunties beach reserve was significantly greater than Cass Bay South in all the preliminary surveys (P < 0.05) (Appendix 3: Table C. 3.3). There were no seasonal differences in abundance at both sites (Appendix 3: Table C 3.4).

Port Levy

At Port Levy, Pa village reserve had a significantly higher mean abundance of cats eyes than Cass Bay North (non-reserve) for all the preliminary surveys (Appendix 3: Table C 3.3). There were no seasonal differences in *Turbo* abundance at both sites (Appendix 3: Table C 3.4).

4.5.2 Shell Lengths

Kaikōura

Avoca Point reserve had a higher *Turbo* mean shell length than Wairepo flats during all the preliminary surveys but this was only significant in autumn (Appendix 3: Table C 3.5). Overall seasonal variations in shell lengths were not significant (P> 0.05) (Appendix 3: Table C 3.6).

Banks Peninsula

Rāpaki reserve

At Cemetery beach reserve the mean shell length of *Turbo* was significantly higher than Corsair Bay only in autumn (Appendix 3: Table C 3.5). There were no seasonal significant differences in mean shell lengths at both sites (Appendix 3: Table 3.6). *Turbo* shell lengths at Aunties beach were significantly higher than Cass Bay South during all the preliminary surveys (Appendix 3: Table C 3.5). There were significant seasonal differences at both sites (Appendix 3: Table 3.6).

Port Levy reserve

At Port Levy, *Turbo* mean shell lengths at Pa village reserve were significantly higher than Cass Bay North throughout the preliminary surveys (Appendix 3: Table 3.5). There were significant seasonal differences in shell lengths at Pa village, while there was variation at Cass Bay North (Appendix 3: Table 3.6)

4.5.3 Adult and Juveniles

Kaikōura

At Avoca Point (reserve) the percentage of juvenile cats eyes (< 25 mm) was slightly higher than adults (> 25 mm) in spring and autumn, but a higher proportion of adults was found in summer (Appendix 3: Figure C 4.5). At Wairepo flats (non-reserve), the percentage of juveniles was higher than adults in spring by 10% and increased to 28% in autumn. In summer, the percentage of juvenile and adult cats eyes were similar (Appendix 3: Figure C 4.5).

Banks Peninsula

Rāpaki reserve

At Rāpaki both Cemetery beach reserve and Corsair Bay (non-reserve) cats eye populations were dominated by juveniles (Appendix 2: Figure C 4.6). The adult *Turbo* population percentage at Aunties beach reserve was slightly higher than juveniles during spring and autumn, but was slightly lower in summer (Appendix 2: Figure C 4.7). At Cass Bay North (non-reserve) the *Turbo* population was dominated by juveniles during all the preliminary surveys (Appendix 3 Figure C 4.7).

Port Levy

At Port Levy, Pa village the *Turbo* adult percentage was higher than the juveniles throughout the preliminary surveys (Appendix 3: Figure C 4.8). At Cass Bay North (non-reserve) on the other hand the cats eye population was dominated by juveniles in all preliminary surveys (Appendix 3: Figure C 4.8).

4.6 Main Survey Results

4.6.1 Abundance and Density

Kaikōura

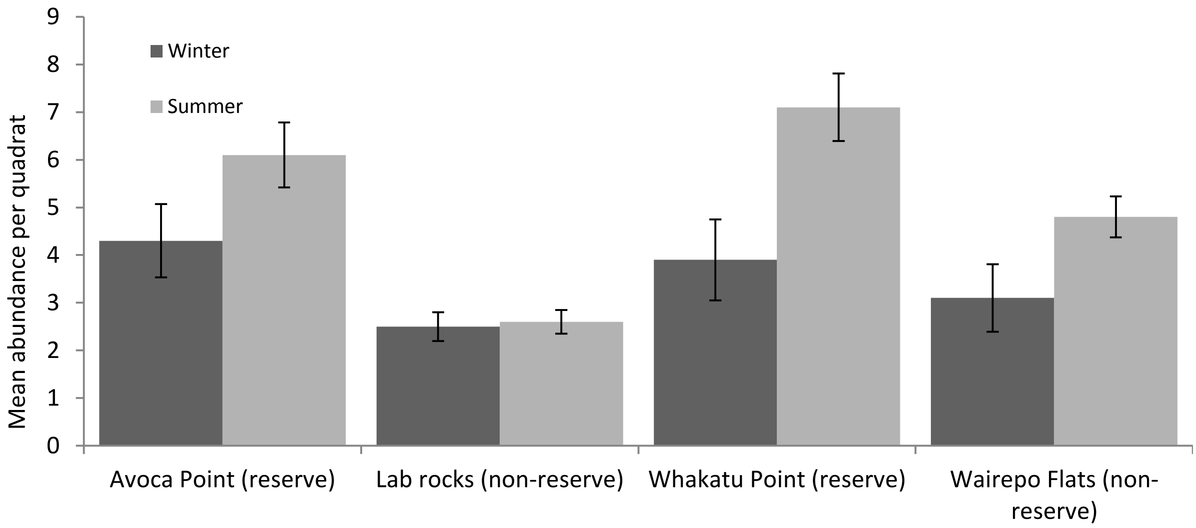


Figure 4.1: *Turbo smaragdus* mean abundance per quadrat (± s.e) collected from pair 1: Avoca Point winter n=173 summer n=242 and Lab rocks winter n=100 summer n=101, and pair 2 Whakatu Point winter n=157 summer n=279 and Wairepo flats winter n=125 summer n=194 during the main surveys in winter August 2011, summer December 2011

Comparison 1: Avoca Point (reserve) and Lab rocks (non-reserve)

The mean abundance of *Turbo* at Avoca Point was greater than Lab rocks during both the winter and summer surveys (Figure 4.1). In winter Avoca Point mean abundance was 4.3 compared to 2.5 at Lab rocks. In summer the abundance at Avoca Point increased to 6.1 while Lab rocks remain basically the same 2.6. The differences between the reserve site at Avoca and non-reserve site at Lab rocks were statistically significantly different in winter and summer ($P < 0.05$) (Table 4.1).

The seasonal variation in mean abundance per quadrat at both Avoca Point and Lab rocks were not significant ($P > 0.05$) (Table 4.2). The density of cats eyes at Avoca Point ranged from 1-23 per quadrat or 10-230 per m² compared to 0-9 per quadrat or 0-90 per m² at Lab rocks. A total of 416 *Turbos* were sampled at Avoca Point compared to 203 at Lab rocks.

Comparison 2: Whakatu Point (reserve) and Wairepo flats (non-reserve)

At Whakatu Point *Turbo* mean abundance per quadrat was higher than Wairepo flats in both the winter and summer surveys (Figure 4.1). The winter mean abundance at Whakatu was 3.9 compared to 3.1 in Wairepo flats. In summer Whakatu recorded 7.1 cats eyes while Wairepo flats had 4.8 In winter densities at the two sites were similar ($P > 0.05$), but in summer the densities were statistically significant ($P < 0.05$) (Table 4.2).

There was a significant seasonal difference in mean abundance per quadrat at both Whakatu Point and Wairepo flats between winter and summer ($P < 0.05$) (Table 4.2). At Whakatu the mean abundance was 3.9 in winter and increased to 7.1 in summer, while Wairepo flats the mean abundance was 3.1 and 4.8 for winter and summer respectively. At Whakatu the density ranged from 1-27 per quadrat or 0-270 per m^2 compared to 0-12 per quadrat or 0-120 per m^2 at Wairepo. A total of 439 *Turbo* was sampled at Whakatu Point compared to 317 at Wairepo flats.

Table 4.1: Results of 1 way ANOVA for *Turbo* average abundance per quadrat between reserve and non-reserve sites. Pair 1: Avoca Point (reserve) and Lab rocks (non-reserve) and pair 2: Whakatu Point (reserve) and Wairepo flats (non-reserve) during the main surveys in winter August 2011 and summer December 2011.

Source of variation	**df**	**MS**	**F**	**P**	**significance**
Pair 1					
Avoca Point & Lab rocks (winter)	1	66.6	4.78	0.032	S
Error	78	13.9			
Avoca Point & Lab rocks (summer)	1	245.0	23.58	0.001	S
Error	78	10.4			
Pair 2					
Whakatu & Wairepo flats (winter)	1	13.60	0.55	0.461	NS
Error	78	24.8			
Whakatu & Wairepo flats (summer)	1	99.0	7.22	0.009	S
Error	78	3.7			

Table 4.2: Results of 1 way ANOVA for *Turbo* comparing the seasonal average abundance per quadrat within reserve and non-reserve sites for the main surveys in winter August 2011 and summer December 2011.

Source of variation	df	MS	F	P	significance
Season					
Avoca Point reserve (winter and summer)	1	61.3	2.89	0.093	NS
Error	78	21.2			
Lab rocks non-reserve (winter and summer)	1	0.11	0.04	0.850	NS
Error	78	3.13			
Whakatu Point reserve (winter and summer)	1	195.3	7.94	0.006	S
Error	78	24.6			
Wairepoflats non-reserve (winter and summer)	1	59.5	4.28	0.042	S
Error	78	13.9			

Banks Peninsula

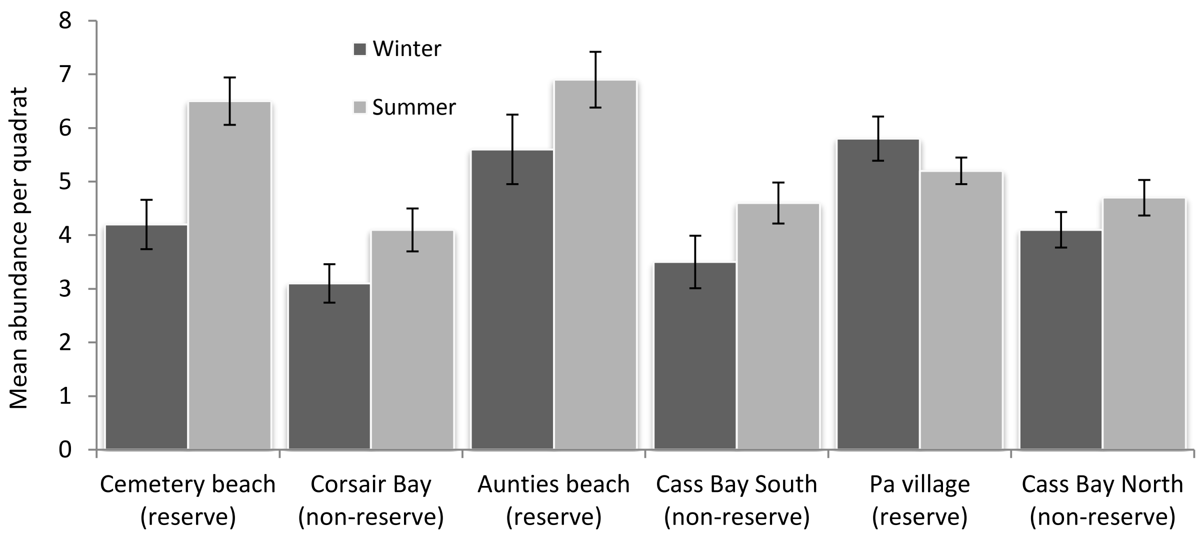


Figure 4.2: *Turbo smaragdus* mean abundance per quadrat (± s.e) collected from pair 1: Cemetry beach winter n=171 summer n=235 and Corsair Bay winter n=125 summer 167 and pair 2: Aunties beach winter n=223 summer n=276 and Cass Bay South winter n=140 summer n=186 and pair 3: Pa village winter n=236 summer n=207 and Cass Bay North winter n=166 summer n=143 during the main surveys in winter August 2011, summer December 2011.

Comparison 1: Cemetery beach and Corsair Bay

The mean abundance per quadrat of *Turbo* at Cemetry beach was greater than Corsair Bay during both the winter and summer surveys (Figure 4.2). For example at Cemetry beach the mean abundance was 4.2 while Corsair Bay recorded 3.1. In summer abundance increased to

6.5 at Cemetery beach while Corsair Bay had 4.1. The difference in abundance between Cemetry beach and Corsair Bay was not significant in winter ($P > 0.05$), but in summer as indicated in (Table 4.3) the difference was statistically significant ($P < 0.05$).

The *Turbo* abundance increased from winter to summer at both Cemetery beach and Corsair Bay, but the increase was higher at Cemetery beach. The seasonal change in abundance at both sites was statistically significant ($P < 0.05$) (Table 4.4). At Cemetry beach the density range from 0-13 per quadrat or 0-130 per m^2 compared to 0- 11 per quadrat or 0-110 per m^2 at Corsair Bay. A total of 429 *Turbo* were sampled at Cemetry beach compared to 288 at Corsair Bay.

Comparison 2: Aunties Beach and Cass Bay South

Aunties Beach had a greater mean abundance of cats eyes per quadrat than Cass Bay South in both winter and summer (Figure 4.2). In winter the abundance was 5.6 compared to 3.5 in Cass Bay South. In summer Aunties beach abundance was 6.9 while Cass Bay South was 4.6. As indicated in Table 4.3, there was a significantly higher abundance of catds eyes at Aunties beach ($P < 0.05$) in both seasons.

There was no significant seasonal difference in mean abundance of cats eyes per quadrat at both Aunties beach and Cass Bay South ($P > 0.05$) (Table 4.4). At Auntie beach the density ranged from 1-14 per quadrat or 0-140 per m^2 compared to 0-9 per quadrat or 0-90 per m^2 at Cass Bay South. A total of 499 *Turbo* were sampled at Auntie beach compared to 327 at Cass Bay South.

Comparison 3: Pa village (reserve) and Cass Bay North (non-reserve)

At Pa village the *Turbo* mean abundance per quadrat was higher than Cass Bay North in both the winter and summer surveys (Figure 4.2). In winter Pa village the mean abundance was 5.8 compared to 4.1 at Cass Bay North. In summer Pa village recorded a mean abundance of 5.2 cats eyes while Cass Bay North had 3.5. In both seasons Pa village abundance was statistically significant ($P < 0.05$) (Table 4.3).

The mean cats eye abundance per quadrat at both Pa village and Cass Bay North was the same ($P > 0.05$) (Table 4.4). In winter the average abundance at Port Levy was 5.8 and this decreased slightly to 5.2 in summer. At Cass Bay on the other hand the mean abundance increased from slightly from 4.1 in winter to 4.7 in summer. The density ranged from 1-11 per quadrat or 10-110 per m² at Pa village compared with 0-9 per quadrat or 0-90 per m² at Cass Bay North. A total of 440 *Turbo* individuals were sampled at Pa village compared with 353 at Cass Bay North.

Table 4.3: Results of 1 way ANOVA for *Turbo* comparing average abundance per quadrat between reserve and non-reserve sites. For pair 1: Cemetery beach (reserve) and Corsair Bay (non-reserve) and pair 2: Aunties beach (reserve) and Cass Bay South (non-reserve) and pair 3: Pa village (reserve) and Cass Bay North during the main surveys in winter August 2011 and summer December 2011.

Source of variation	df	MS	F	P	significance
Pair 1					
Cemetery beach & Corsair Bay (winter)	1	26.45	3.75	0.056	NS
Error	78	7.06			
Cemetery beach & Corsair Bay (summer)	1	112.8	15.68	0.001	S
Error	78	7.19			
Pair 2					
Aunties beach & Cass Bay South (winter)	1	86.11	6.52	0.0126	S
Error	78	13.2			
Aunties beach & Cass Bay South (summer)	1	99.0	11.69	0.001	S
Error	78	8.47			
Pair 3					
Pa village & Cass Bay North (winter	1	56.1	9.88	0.002	S
Error	78	5.7			
Pa village & Cass Bay North (summer)	1	51.20	14.39	0.001	S
Error	78	3.56			

Table 4.4: Results of 1 way ANOVA for *Turbo* comparing seasonal average abundance within reserve and non-reserve sites for winter August 2011 and summer December 2011.

Source of variation	df	MS	F	P	significance
Season					
Cemetery beach reserve (winter and summer)	1	108.11	13.09	0.001	S
Error	78	8.26			
Corsair Bay non-reserve (winter and summer)	1	24.20	4.04	0.048	S
Error	78	5.99			
Aunties beach reserve (winter and summer)	1	35.1	2.53	0.116	NS
Error	78	13.9			
Cass Bay South non-reserve (winter and summer)	1	27.61	3.55	0.063	NS
Error	78	7.78			
Pa village reserve (winter and summer)	1	8.45	1.78	0.186	NS
Error	78	4.74			
Cass Bay North non-reserve (winter and summer)	1	6.61	1.47	0.229	NS
Error	78	4.50			

4.6.2 Shell Lengths

Kaikōura

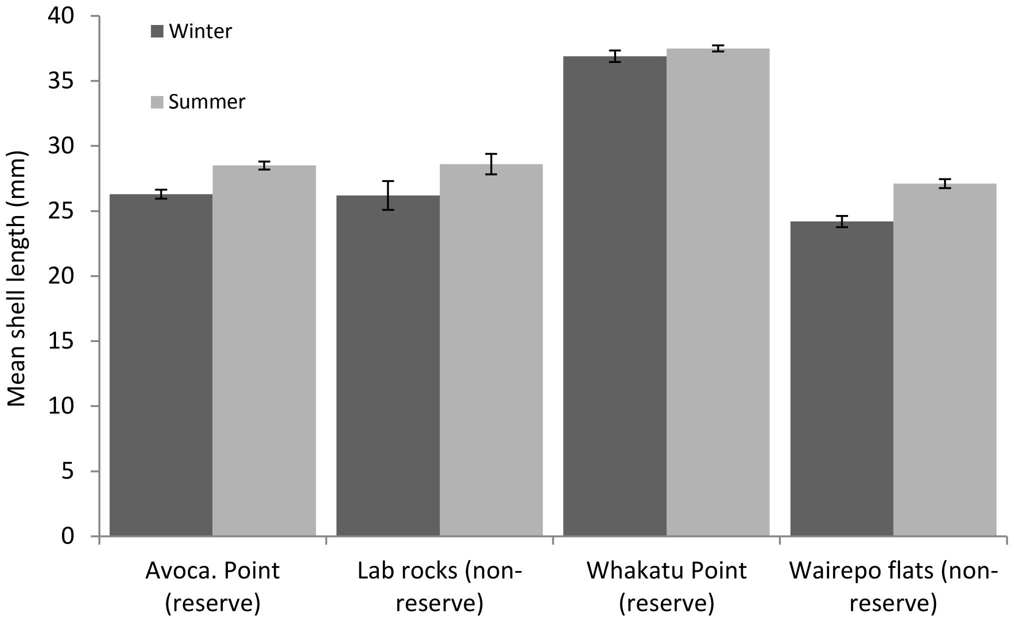


Figure 4.3: *Turbo smagradus* seasonal mean shell length (± s.e) collected from pair 1:Avoca Point (reserve) and Lab rocks (non-reserve site) and pair 2: Whakatu Point (reserve) and Wairepo flats (non-reserve) during the main surveys in winter August 2011 and summer December 2011.

Comparison 1: Avoca Point (reserve) and Lab rocks (non-reserve)

At site 1 the winter the mean shell length of cats eyes at Avoca Point (26.3 mm) was similar to Lab rocks (26.2 mm) (Figure 4.3). In summer Avoca Point mean shell length was 28.5 mm while Lab rocks had 28.6 mm. The shell length at both sites increased in summer (Figure 4.3). There were no significant differences in shell length between the two sites in both winter and summer.

There were highly significant seasonal differences in mean shell of cats eyes at Avoca Point, the summer shell length was significantly different from winter ($P < 0.05$) (Table 4.6). At Lab rocks on the other hand there was no seasonal variation in shell length (Table 4.6).

Comparison 2: Whakatu Point (reserve) and Wairepo flats (non-reserve)

At Whakatu point the mean shell length was significantly different from Wairepo for both the winter and summer surveys ($P < 0.05$) (Table 4.5). In winter Whakatu mean shell length was 36.8 mm compared to 24.2 at Wairepo. In summer Whakatu cats eyes were 37.5 mm while Wairepo had 27.5 mm (Figure 4.3). *Turbo* individuals at Whakatu Point were mostly large adults and this contribute to the differences.

There was no significant seasonal variation in shell lengths for cats eyes at Whakatu Point but at Wairepo flats there were significant differences (P < 0.05) (Table 4.6). The number of adult *Turbo* (> 30mm) found at Wairepo increased in summer and this contributed to the differences.

Table 4.5: Results of 1 way ANOVA for *Turbo* comparing the average shell lengths between reserve and non-reserve sites. For pair 1: Avoca Point (reserve) and Lab rocks (non-reserve), pair 2: Whakatu Point (reserve) and Wairepo flats (non-reserve) during the main surveys in winter August 2011 and summer December 2011.

Source of variation	**df**	**MS**	**F**	**P**	**significance**
Pair 1					
Avoca Point & Lab rocks (winter)	1	0.2	0.00	0.956	NS
Error	271	19001.0			
Whakatu & Wairepo flats (summer)	1	11170.4	93.67	0.001	S
Error	280	28.4			
Pair 2					
Avoca Point & Lab rocks (winter)	1	1.7	0.05	0.830	NS
Error	341	36.9			
Whakatu Point & Wairepo flats (summer)	1	12446.4	609.32	0.001	S
Error	471	20.4			

Table 4.6: Results of 1 way ANOVA for *Turbo* comparing the seasonal average shell length within reserve and non-reserve sites for winter August 2011 and summer January 2012.

Source of variation	**df**	**MS**	**F**	**P**	**significance**
Season					
Avoca Point reserve (winter & summer)	1	493.2	14.45	0.001	S
		34.1			
Error	413	295.0	3.36	0.068	NS
Lab rocks non-reserve (winter &summer)	1	87.8			
Error	197	36.9	1.66	0.199	NS
Whakatu Point reserve (winter & summer)	1	22.3			
Error	434	615.7	24.70	0.001	S
Wairepoflats	1	24.9			
non-reserve (winter & summer)	317				
Error					

Banks Peninsula: Rāpaki and Port Levy reserves

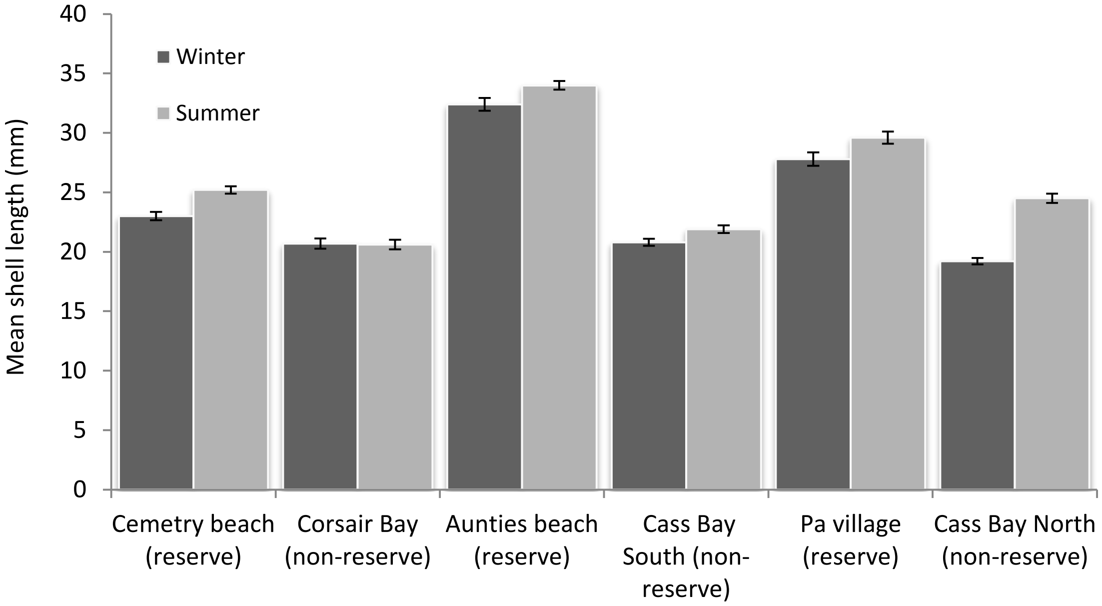


Figure 4.4: *Turbo smagradus* mean shell length (± s.e) collected from pair 1:Cemetery beach (reserve) and Corsair Bay (non-reserve site), pair 2: Aunties beach (reserve) and Cass Bay South (non-reserve) and pair 3: Pa village (reserve) and Cass Bay North (non-reserve) during the main surveys in winter August 2011 and summer January 2011.

Comparison 1: Cemetery beach and Corsair Bay

The mean shell length at Cemetery beach was significantly greater than Corsair Bay in both the winter and summer surveys (Figure 4.4) $P < 0.05$ Table 4.7). Cemetery beach cats eye mean shell length increased slightly in summer, in contrast Corsair Bay cats eyes were smaller.

There were significant seasonal differences in mean shell for cats eyes from Cemetery beach ($P < 0.05$) (Table 4.8). There were greater numbers of large *Turbo* in summer compared to winter and this contributed to the seasonal differences. In contrast, at Corsair Bay the seasonal variation in shell length was not significant (Table 4.8)

Comparison 2: Aunties beach and Cass Bay south

At Aunties beach, cats eye mean shell length was statistically significantly different from Cass Bay South in both the winter and summer surveys ($P < 0.05$) (Table 4.7). In both seasons Aunties beach had a higher number and larger size *Turbo* compared with Cass Bay South and this contributed to the differences.

There were seasonal differences in the mean shell length of cats eyes from both Aunties beach and Cass Bay South ($P < 0.05$) (Table 4.8). At both sites the summer mean shell length was higher than winter (Figure 4.4).

Comparison 3: Pa village (reserve) and Cass Bay North (non-reserve)

The *Turbo* mean shell length at Pa village was higher than Cass Bay North in both the winter and summer surveys. The mean shell lengths were 27.8 mm in winter and 29.6 mm in summer. In comparison Cass Bay North cats eyes were 19.2 mm in winter and 24.4 mm in summer. The difference in shell length between the two sites was statistically significant in both winter and summer ($P < 0.05$) (Table 4.7). The seasonal variation in mean shell length at both Pa village and Cass Bay North were statistically significant ($P < 0.05$) (Table 4.8). At both sites the summer mean shell length for cats eyes was clearly higher than in winter (Figure 4.4).

Table 4.7: Results of 1 way ANOVA for *Turbo* comparing the mean shell lengths between reserve and non-reserve sites, pair 1: Cemetery beach (reserve) and Corsair Bay (non-reserve), pair 2: Aunties beach (reserve) and Cass Bay South (non-reserve), pair 3: Pa village (reserve) and Cass Bay North (non-reserve) during the main surveys in winter August 2011 and summer January 2012

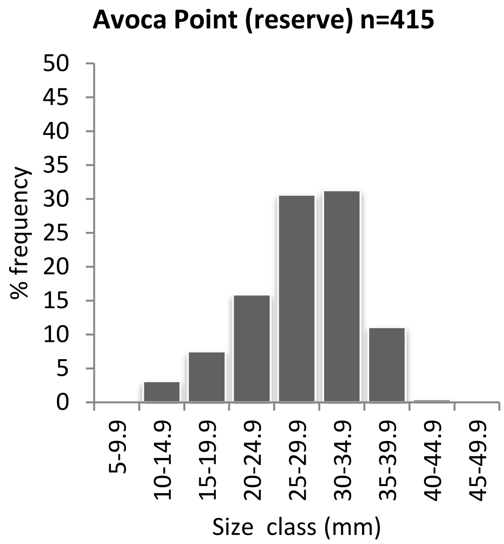
Source of variation	df	MS	F	P	significance
Pair 1					
Cemetery beach & Corsair Bay (winter)	1	380.5	9.02	0.003	S
Error	294	42.2			
Cemetery beach & Corsair Bay (summer)	1	2146.3	58.73	0.001	S
Error	426	36.5			
Pair 2					
Aunties beach & Cass Bay South (winter)	1	11556.9	260.50	0.001	S
Error	361	44.4			
Aunties beach & Cass Bay South (summer)	1	16471.3	548.81	0.001	S
Error	459	30.0			
Pair 3					
Pa village & Cass Bay North (winter)	1	7305.9	135.94	0.001	S
Error	400	53.7			
Pa village & Cass Bay North (summer)	1	2326.7	45.38	0.001	S
Error	348	51.3			

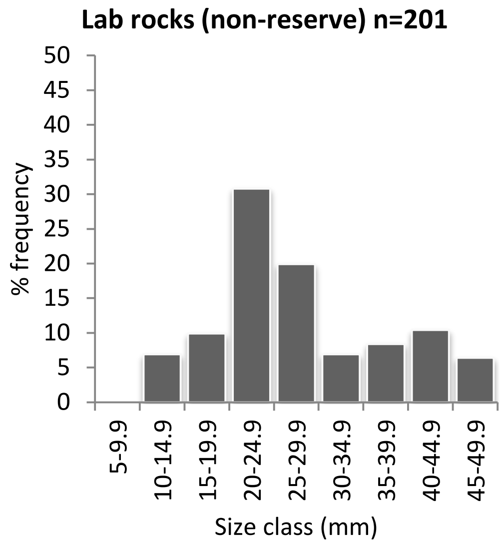
Table 4.8: Results of 1 way ANOVA for *Turbo* comparing the seasonal average shell length within reserve and non-reserve sites for winter August 2011 and summer January 2012.

Source of variation	Df	MS	F	P	Significance
Season					
Cemetery beach reserve (winter & summer)	1	506.5	12.00	0.001	S
Error	430	42.2			
Corsair Bay non-reserve (winter & summer)	1	0.5	0.01	0.906	NS
Error	290	33.9			
Aunties beach reserve (winter & summer)	1	329.1	6.75	0.010	S
Error	497	48.8			
Cass Bay South (non-reserve (winter & summer)	1	84.7	4.93	0.027	S
Error	324	17.2			
Pa village reserve (winter & summer)	1	329.0	4.43	0.036	S
Error	441	74.3			
Cass Bay North non-reserve (winter & summer)	1	2030.2	94.55	0.001	S
Error	307	21.5			

4.6.3 Size Structure

Kaikōura





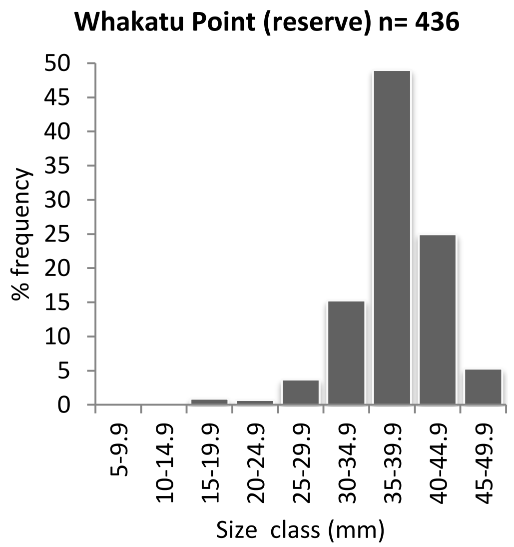


Figure 4.5: Combined samples of winter and summer size frequencies of *Turbo smaragdus* at Kaikōura's Avoca Point and Whakatu Point (reserve) and Lab rocks and Wairepo flats (non-reserve).

Comparison 1: Kaikōura Avoca Point (reserve) and Lab rocks (non-reserve)

At Avoca Point the size frequency distribution was unimodal and the mode occurred at 30-34.9 mm (Figure 4.5). At Lab rocks there appeared to be a bimodal size frequency distribution developing. The first mode occurred at 20-24.9 mm size class, which made up about 32% of the population and the minor mode at 40-44.9 mm size class. The size range at

Lab rocks was wider compared to Avoca Point (Figure 4.5). The largest size class recorded at Avoca Point was between 35-39.9 mm while at Lab rocks it was 45-49.9 mm.

Comparison 2: Kaikōura Whakatu Point (reserve) and Wairepo flats (non- reserve)

Both sites had a unimodal distribution. The Whakatu population was clearly dominated by size class 35-39.9 mm which made up 49% of the population. At Wairepo the modal size class occurred between 25-29.9 mm, which made up about 32% of the population. About 30% of the *Turbo* sampled at Whakatu were between the size ranges 40-49.9 mm, whereas at Wairepo flats there was only 0.3%.

Banks Peninsula: Rāpaki and Port Levy reserve

Comparisons 1: Rāpaki Cemetery beach (reserve) and Corsair Bay (non-reserve)

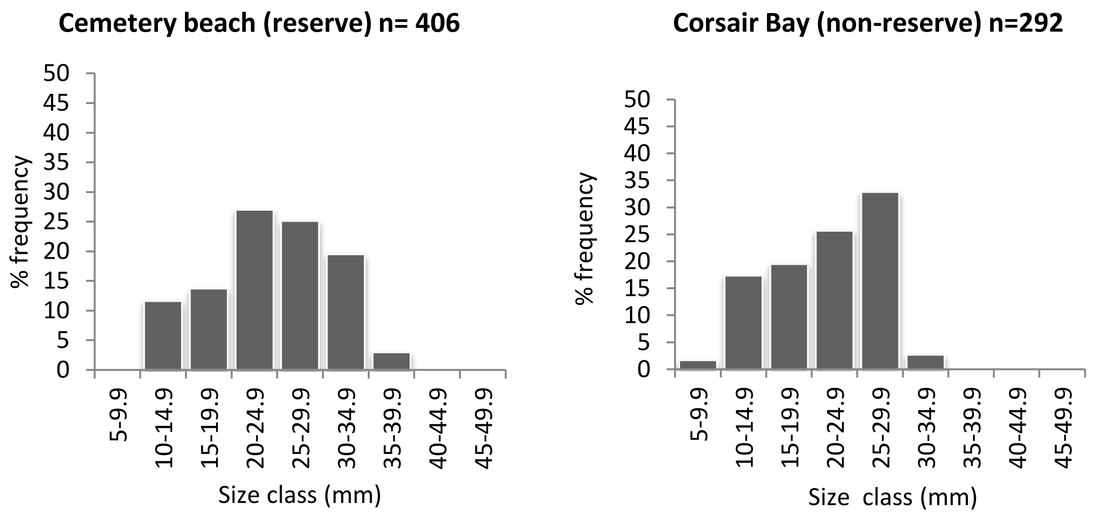
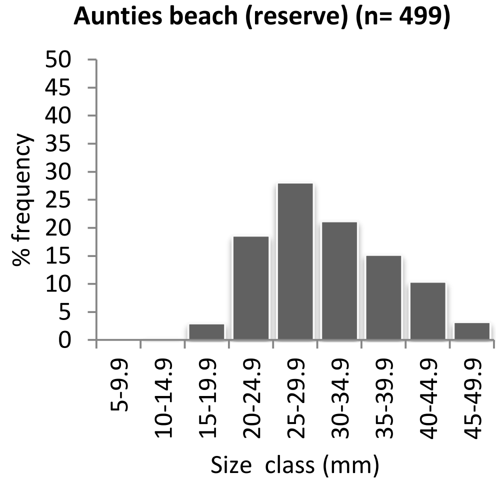


Figure 4.6: Combined samples of winter and summer size frequencies of *Turbo smaragdus* at Rapaki Cemetery beach (reserve site) and Corsair Bay (non-reserve site)

At Cemetery beach *Turbo* population size distribution appeared more normally distributed than Corsair Bay, which is positively skewed. At Cemetery beach the mode occurred at size class 25-29.9 mm while at Corsair Bay there was a clear mode at size class 20-24.9 mm. (Figure 4.6). Large turbos (> 40 mm) were scarce at both sites

Comparison 2: Rāpaki Aunties beach (reserve) and Corsair Bay South (non-reserve)



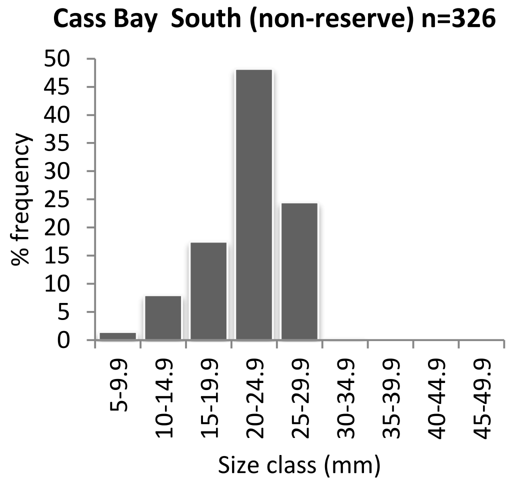
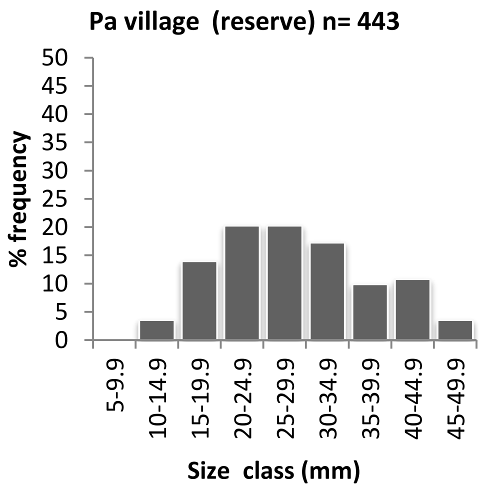


Figure 4.7: Combined samples of winter and summer size frequencies of *Turbo smaragdus* at Rāpaki Aunties beach (reserve site) and Cass Bay South (non-reserve site)

The size range of *Turbo* at Aunties beach was wider than Cass Bay South. For example, at Aunties beach, the size ranged from 10-14.9 to 45- 49.9 mm compared to 5.9.9–25-29.9 mm at Cass Bay South (Figure 4.6). While 50% of the *Turbo* population at Aunties beach was made up of large cats eyes (> 30 mm) in shell size, in contrast Cass Bay North had none. There was a clear mode at size class 25-29.9 mm at Aunties beach (Figure 4.6). About 28% of the *Turbo* population were made up of this size class and small variations in the percentage of *Turbo* of other size classes. At Cass Bay South there was a distinct mode at size class 20-24.9 mm, which contributed to about 48% of the population.

Comparison 3 : Port Levy Pa village (reserve) and Cass Bay North (non-reserve)



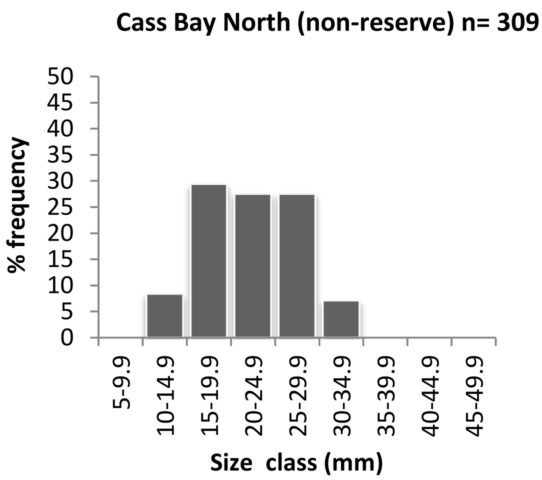


Figure 4.8: Combined samples of winter and summer size frequencies of *Turbo smaragdus* at Port Levy's Pa village (reserve site) and Cass Bay South (non-reserve site)

At Port Levy, Pa village had a wider range of size classes of *Turbo* compared to Cass Bay North. *Turbo* recorded at Pa village ranged in size from 10-14.9 to 45-49.9 mm (Figure 4.7). In comparison, at Cass Bay North the size range was from 10-14.9 to 30- 34.9 mm (Figure 4.7). At Pa village large *Turbo* (> 30 mm) made up about 42% of the population compared to about 7% at Cass Bay Nort

4.6.4 Adult and Juveniles

Kaikōura

Comparison 1: Kaikōura Avoca Point (reserve) and Lab rocks (non-reserve)

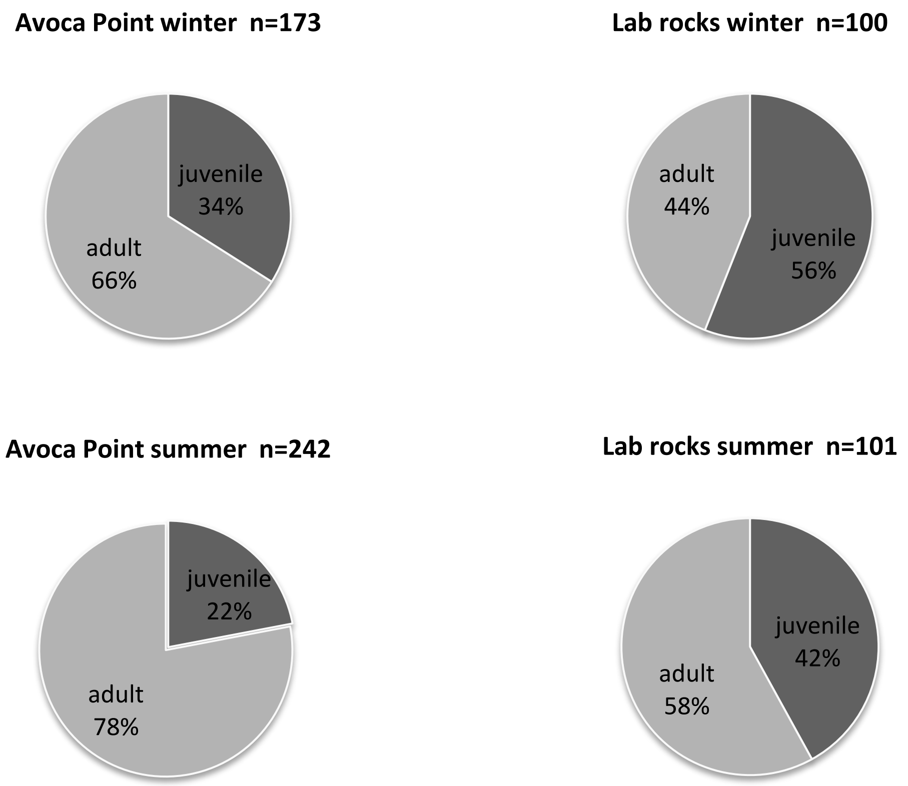


Figure 4.9: Percentage of juvenile (< 25 mm) and adult (> 25 mm) of *Turbo* population at Avoca Point (reserve) and non-reserve site at Lab rocks during the main survey in winter 2011 and summer January 2012

At Avoca Point there were more adult *Turbo* than juveniles in both winter and summer (Figure 4.8). In winter adult *Turbo* made up 66% of the population and increased to 78% in summer. In comparison Lab rocks adult populations were variable, in winter it was 44 % and in summer increased to 58%.

A Chi-square goodness of fit test was used to determine whether the expected ratios of 28% juvenile and 72% adults were found in the main surveys. At the Avoca reserve site the ratios followed the expected values (P > 0.05). At Lab rocks on the other hand there were significant differences between the expected and observed values (P > 0.05) (Chi- square goodness of fit test).

Comparison 2: Kaikōura Whakatu Point (reserve) and Wairepo flats (non-reserve)

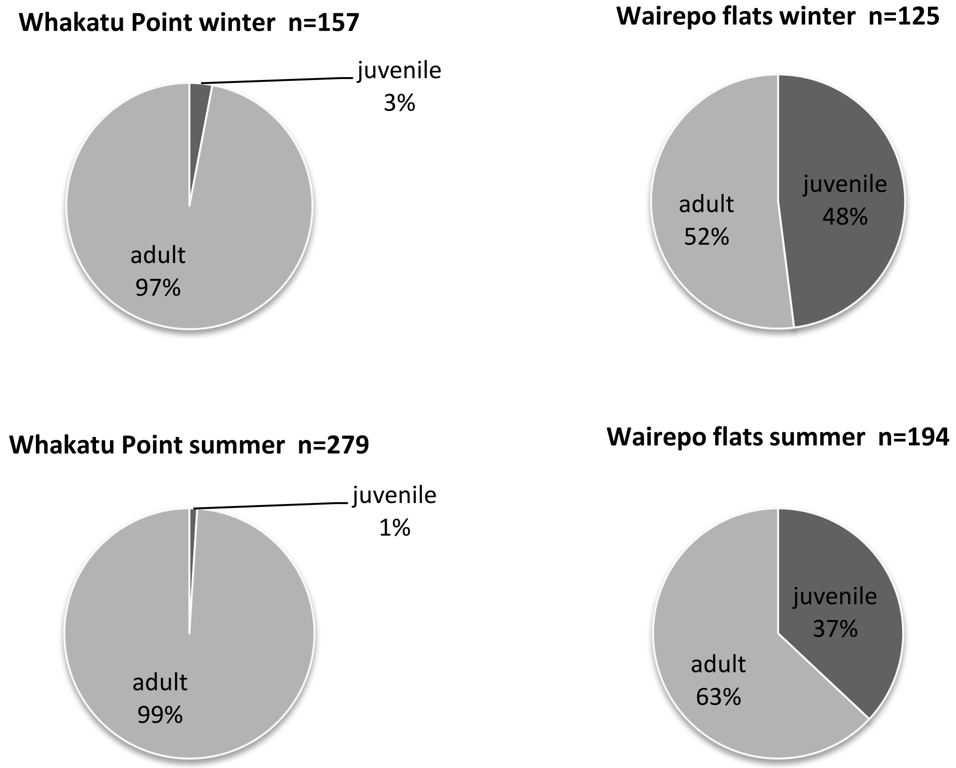


Figure 4.10: Percentage of juvenile (< 25 mm) and adult (> 25 mm) of *Turbo* population at Whakatu Point (reserve) and non-reserve site at Wairepo flats during the main survey in winter August 2011 and summer January 2012.

The population of *Turbo* at Whakatu Point was predominantly adult, 97% in winter and 99% in summer (Figure 4.9). At Wairepo flats the adult population made up 48% of the population in winter and 63% in summer. Chi-square goodness of fit test was used to determine the expected ratios of 28% juvenile and 72% adult to the observed ratio at both sites in winter and summer. At Whakatu Point the differences between the expected and observed values were not significant in both the winter and summer surveys (P > 0.05). At Wairepo flats on the other hand the differences between the expected and observed values were statistically significant (P > 0.05) in both seasons (Chi- square goodness of fit test).

Banks Peninsula**: **Rāpaki and Port Levy reserve

Comparison 1: Rāpaki Cemetery beach (reserve) and Corsair Bay (non-reserve)

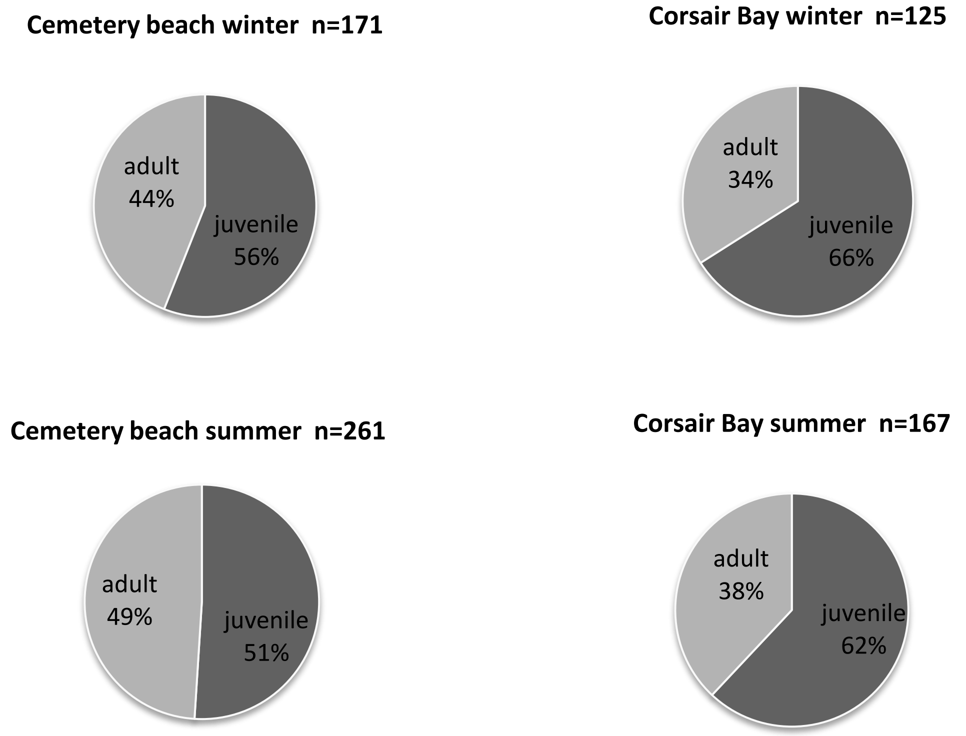


Figure 4.11: Percentage of juvenile (< 25 mm) and adult (> 25 mm) of *Turbo* population at Cemetery beach (reserve) and non-reserve site at Corsair Bay during the main survey in winter August 2011 and summer January 2012

The percentage of juvenile *Turbo* was greater than adults at the resereve site at Cemetery beach as well as the non reserve site at Corsair Bay (Figure 4.10) in both the winter and summer surveys. The juvenile percentage at Corsair Bay though, was slightly higher than Cemetery beach in both seasons, 66% in winter and 62% in summer compared to 56% and 51% at Cemetery beach for the same period. Chi-square goodness of fit test was used to determine the expected ratios of 54 % juvenile and 46% adult to the observed ratio at both sites in winter and summer. At Cemetery beach the ratios followed the expected values in both the winter and summer surveys ($P > 0.05$). At Corsair bay on the other hand the differences between the expected and observed values were significant in winter ($P > 0.05$) but not significant in summer (Chi- square goodness of fit test)

Comparison 2: Rāpaki Aunties beach (reserve) and Corsair Bay South (non-reserve)

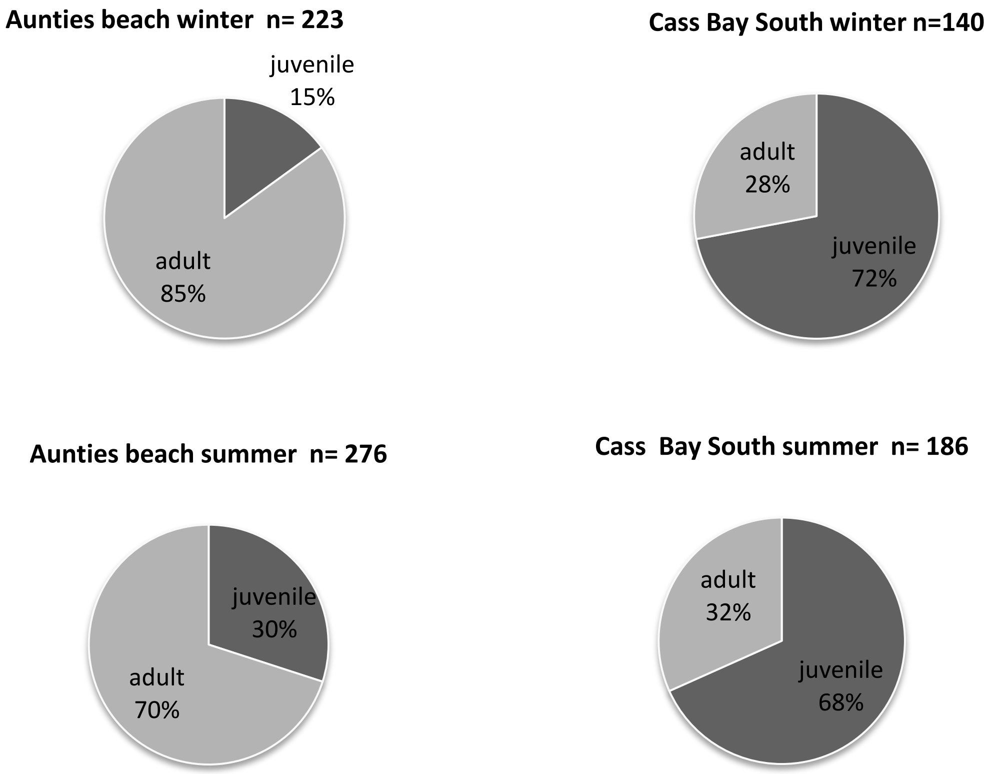


Figure 4.12: Percentage of juvenile (< 25 mm) and adult (> 25 mm) of *Turbo* population at Aunties beach (reserve) and non-reserve site at Cass Bay South during the main survey in winter August 2011 and summer January 2012

At Aunties beach the *Turbo* population was dominated by adults in both winter and summer surveys (Figure 4.11). In winter 85% were adults and it decreased to 70% in summer. In contrast, at Cass Bay South, juveniles were dominant in both seasons, being 72% in winter and 68% in summer**.** While the adult population decreased by 15% at Aunties beach in summer, Cass Bay South on the other hand had a small increase of 4% in the same period. Chi-square goodness of fit test was used to determine the expected ratios of 23% juvenile and 77 % adult to the observed ratio at both sites in winter and summer. At Aunties beach the ratios followed the expected ratios in both the winter and summer surveys ($P > 0.05$). At Cass Bay South on the other hand the differences between the expected and observed values were statistically significant in both winter and summer ($P > 0.05$) (Chi-square goodness of fit test**).**

Comparison 3 : Port Levy Pa village (reserve) and Cass Bay North (non-reserve)

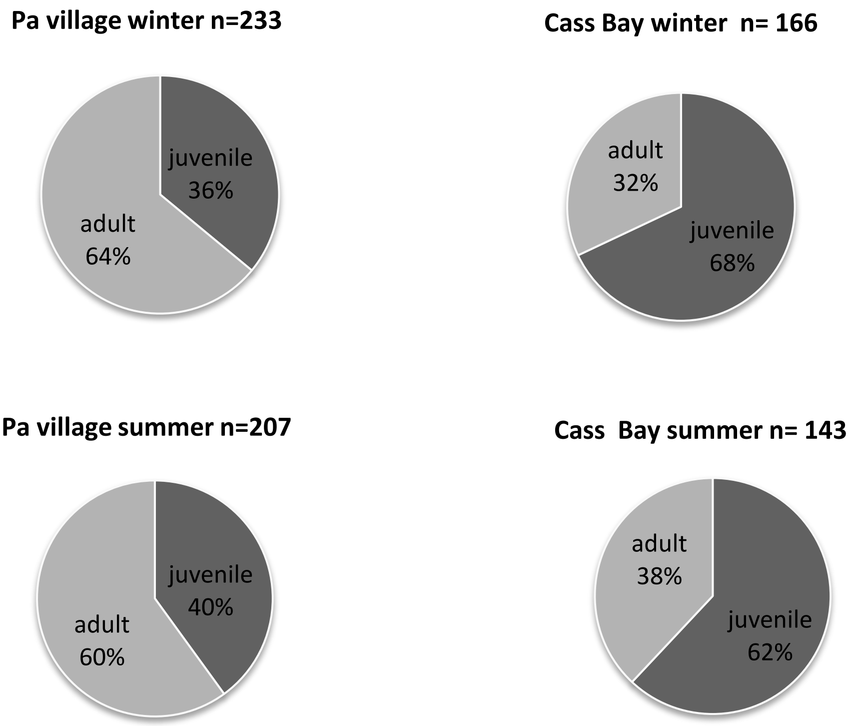


Figure 4.13: Percentage of juvenile (< 25 mm) and adult (> 25 mm) *Turbo* population at site Pa village (reserve) and non-reserve site at Cass Bay North during the main survey in winter August 2011 and summer January 2012.

At Pa village the ratio of adult and juvenile *Turbo* population in winter and summer were similar (Figure 4.12), with more adults than juveniles in both seasons. For example in winter the ratio were 64% adult and 36% juvenile while in summer there were 60% adult and 40% juvenile. In summer there was a slight decrease in the adult population and a corresponding increase in the percentage of juveniles**.** At Cass Bay North, like Pa village the ratio of adults and juvenile *Turbo* were very similar in winter and summer, but in contrast to Pa village the juveniles were more abundant in Cass Bay North (Figure 4.12). For example there were 68% juveniles in winter and 32% adults while in summer there were 62% juveniles and 38% adults. Chi-square goodness of fit test was used to determine the expected ratios of 38% juvenile and 62% adult to the observed ratio at both sites in winter and summer. At Pa village the ratios followed the expected ratios both the winter and summer surveys ($P > 0.05$). At Cass Bay North on the other hand the differences between the expected and observed values were statistically significant in both winter and summer ($P > 0.05$) (Chi-square goodness of fit test). The ratios of adult and juvenile *Turbo* between the two sites were significantly different**.**

4.7 Discussion

4.7.1 Abundance and Density

The abundances of *Turbo* in reserve and non-reserve sites during the preliminary and main surveys were variable. Also, there were seasonal variations in some populations. There was however a general pattern of higher densities in reserve areas compared with non-reserve areas. Out of the four reserve sites surveyed in the preliminary surveys, two sites (Aunties beach and Pa village) had significantly higher cats eye abundance compared to their corresponding non-reserve sites. For the other two reserve sites (Avoca Point and Cemetery beach), the densities were similar to their non-reserve comparisons. In the main survey, out of the five reserve sites surveyed three sites (Avoca Point, Aunties beach and Pa village), densities of cats eyes were significantly higher in both winter and summer compared to their corresponding non-reserve sites. For the two other reserve sites (Whakatu Point and Cemetery beach), significantly higher cats eye abundance were found in summer.

Many factors including food availability, intraspecific and interspecific competition can affect gastropod abundance and density (Underwood, 1979; Underwood and Denley, 1984) in rocky intertidal habitats. The quality and quantity of the food resource is, however, a much more important factor determining the patterns of movement and distribution of Gastropoda (Apolinario, et al. 1999). In the present study, food availability may explain in part the differences in abundance between reserve sites and non- reserve sites. Also the environment conditions at the reserve site may have been better for cats eyes. Further research is needed to understand these differences.

Studies on the distribution of *Turbo* across rocky intertidal zones have indicated that their density and size increases at lower tidal levels (Walsby, 1977; Creese, 1998). Studies of *Turbo* distribution in the Auckland region (Beckett, 1969) and at Kaikōura (Robinson, 1992) have found that larger *Turbo* occur in the shallow sub-littoral zones. In the present study *Turbo* abundance and size increased at the lower shore levels at all study sites. The highest density range of *Turbo* found in this study was 270 m². This is similar to other studies from various regions of the world 250 m² (Indonesia – Ompi, 1994), 200 m² in South Africa (Foster and Hodgson, 2000). The result of the present study suggests that *Turbo* aggregate in the lower shore. According to Underwood (1976) aggregated distributions of intertidal molluscs have been detected in many intertidal species (e.g. *Nerita atramentosa and*

Bembicium nanum). Aggregation maybe the consequence of the migration of some individuals to habitats that are favourable for survival during periods of emergence at low tide (Robinson, 1992).

This study found that at four out of the ten sites surveyed (Whakatu (reserve), Wairepo (non-reserve), Cemetery (reserve) and Corsair Bay (non-reserve)), there were significant seasonal differences in abundance of cats eyes between the winter and summer. At all four sites *Turbo* abundances increased significantly in the lower shore in summer. Two studies of *Turbo* populations in New Zealand offer explanations about population movement. In the North Island Alfaro (2006) suggested that *Turbo* may aggregate in the low intertidal–shallow subtidal areas on rocky shores in summer where macroalgae tend to be more abundant. According to Robinson (1992) *Turbo* in the upper littoral zone at Kaikōura region can be exposed to long periods of aerial exposure and extremes of temperature and desiccation during low tide. *Turbo* therefore move to the **s**ub-littoral region where they would normally be submerged longer. Studies from other parts of the world have also found seasonal changes in populations of gastropods in relation to temperature and tides. For example in Thailand abundance of limpets showed significant differences with tidal level and season (Samakraman, et al. 2009). In Japan the intertidal gastropod *Monodonta labio* migrate downward to the lower zone in summer because of temperatures (Takada, 1995). The density and distribution of grazing tropical snails may change with tidal regime, day and night cycles, and seasons (Levings and Garity, 1983; Nickel and Sayer, 1998; Hutchinson and Williams, 2003). Other studies have suggested that the density of intertidal gastropods can be affected by other abiotic factors such as wave action, temperature and desiccation (Atkinson and Newbury, 1984; Raffaelli and Hawkins, 1996; Tanaka, et al. 2002). On rocky shores, if refuges such as holes and crevices are in short supply and high temperatures may stimulate animals to migrate down the shore (Raffaelli and Hughes, 1978).

The present study suggests that the increased abundance of *Turbo* in summer at the lower intertitdal zones at both the reserve and non-reserve sites could be explained by the higher temperatures experience in the rocky intertidal areas in summer compared to winter. *Turbo* would move down to the lower shores not only for moist conditions but also for availability of food. The lack of holes and crevices in the rocky shores at the reserve site at Cemetery beach as well as non-reserve site at Corsair Bay may have resulted in more *Turbo* moving into the lower shore in summer. These sites have barnacles and algae which may provide a moister habitat than crevices and bare rock surfaces at the mid intertidal areas.

4.7.2 Shell Lengths

For the main survey, when sampling intensity was increased and concentrated in the low tide, it was found that that mean shell length of cats eyes at the reserve sites were significantly higher than for most non-reserve sites (all but one site). Many factors influence the growth rate of shellfish and the maximum shell size. The high mean shell length of *Turbo* in the reserve areas could be due to many reasons. One of the most important influences on shell size in marine organisms appears to be the animal's own growth rate (Urdy et al., 2010a, b), which can be influenced by environmental factors such as food availability and quality, and feeding time (Saunders, et al. 2009). The availability of food resources have also been considered responsible for the differences in growth rates in intertidal zones (Takada, 1995). Cerrato and Keith (1992) investigated the growth and maximum sizes of shellfish and found that the size of older individuals varied widely owing to environmental induced stress. Although differences in mean shell length can due to many complex factors which are difficult to determine, this study suggests that the greater availability of food resources in reserve sites could be the reason why mean shell lengths are higher in the reserve sites compared to non-reserve sites.

4.7.3 Size Structure

In many invertebrate species the population size distribution could be the result of inconsistencies in recruitment patterns (King, 1995). Poor recruitment for a few years, as a result of unsuccessful spawning or larval mortality, could result in the absence of smaller animals. In the current study the lack of juveniles (< 10 mm) from most sites could be due to the sampling methodology. In this study the main survey was concentrated at the lower shore where larger *Turbo* are known to occur. This adult dominated population may not be representative of the population structure at all shore levels. Some juveniles (< 10 mm) were found in small numbers at two non-reserve sites at Corsair Bay and Cass Bay, confirming recruitment had occurred from the previous spawning season (Robinson, 1992). The narrow intertidal at the two sites may explain why juveniles of this size were found on the lower shore compared to other sites which have a wider and more distinguishable physical gradient.

Different growth rates of populations at distinct geographical regions can happen (Breen, 1980; Tegner, 1989). This may be due to not only the differences in habitat but availability of food as well as the quality and the quantity of food between the geographical regions. Natural mortality due to unfavourable conditions, lack of food, competition, high levels of predation (King, 1995) could be higher in some coastal regions, thereby causing variation in size classes between sites.

In the present study size ranges of *Turbo* in reserve sites are wider than those at non-reserve sites. Three out of five reserve sites have large class sizes between 40-50 mm compared to one from the non-reserve sites. The non-reserve sites have higher juvenile population compared to reserve sites. The presence of more large adults in the reserve sites can be due to higher availability of food. Only experimentation (Schiel and Breen, 1991) or long term series of data from extensive sampling can explain the cause of any observed differences in size distribution (Hayashi, 1980). The lack of population data from the three reserves makes it impractical for the present study to associate the presence of large adults in the three reserves to protection.

4.7.4 Adult and Juveniles

Studies on intertidal animals suggest that vertical size gradients are established or maintained by different movements of individuals of different sizes (Gendron, 1977; McQuaid, 1981; McCormack, 1982). Many intertidal species have behavioural adaptations including the selection of particular microhabitats that minimise the effects of thermal extremes and desiccation (Garrity, 1984; Cowie, 1985; Marchetti and Geller, 1987). More complex microhabitats (those including barnacles and algae) in the lower intertidal zone offered snails may provide more protection from dehydration than less complex microhabitats such as crevices and rock surfaces (Marchetti and Geller, 1987). Selection of a less stressful microhabitat has been previously reported as a behavioural adaptation used by temperate intertidal snails to control their internal temperature (e.g., *Colisella digitalis*, Gallien, 1985; and *Morula marginalba*, Moran, 1985). Large snails select more complex habitats on warm days than on cool days while small snails remained in the less complex microhabitats, even though their water loss rates are predicted to be higher in these exposed areas (Jones, 1996). High temperature in summer on rocky shores may cause large snails to migrate down the shore if holes and crevices were in short supply, while juveniles and small snails could escape into refuges (Emson and Faller-Fritsch, 1976; Raffaelli and Hughes, 1978). In South Africa, McLchlan, et al. (1980) revealed that large *Turbo sarmaticus* are more susceptible to rapid temperature changes than smaller individuals.

The present study found higher abundances of adult cats eyes in the lower intertidal areas in summer in eight out of ten sites surveyed. This increase in adult abundance in the lower shore in summer could be due to migration towards the lower shore which offers *Turbo* more protection from dehydration. The decrease in the percentage of adult cat's eyes in reserve sites at Rāpaki (Aunties beach) and at Port Levy (Pa village) in summer may be associated with harvesting. Hartill and Cryer (1999) observed that the greatest shellfish harvesting occurred in summer and was lowest in winter. The unavailability of customary harvest data makes it difficult to associate with any certainty that the decrease of adult *Turbo* population at the two reserve sites was due to harvesting. The percentages of adult cats eyes (> 25 mm) were higher in all reserve sites compared to non-reserve sites. Harvesting is often associated with low abundance of large adults in non-reserve areas. During the entire survey period I did not find anyone collecting *Turbo* at either the reserve sites or the non-reserve sites. Kaitiaki from Port Levy and Rāpaki reported in interviews that, although cats eyes are not popular as food now as they used to be, some community members still harvest them. The presence of larger adults in the reserves may be because they are not harvested as much now as they were in the past or because reserve sites provide better growth or a combination of both. Again the lack of recreational and customary harvest data makes it difficult to associate the low abundance of large *Turbo* in non- reserve sites with harvesting.

4.8 Conclusion

In summary, this study has shown clear differences in the cats eye resources between reserve and non-reserve areas in the Canterbury Region. While these differences do not confirm that management in the marine reserves is effective, the higher abundances of large cats eyes in the reserve areas reflect environmental values which appear able to support cultural harvesting.

Chapter 5: Cultural Evaluation of Customary Fisheries Management in Canterbury

5.1 Introduction

Customary management systems are cultural and historical systems created to control the usage, entry, and allocation of resources within a community. They are enlightened by indigenous knowledge and deeply rooted in customary land and sea tenure institutions (Cinner and Aswani, 2007). Traditional ecological knowledge is an important component of customary fisheries management. Local fishers have first-hand understanding and knowledge of the local environment they exploit, including knowledge about the direct assessment of local marine stocks and how they change over time (Aswani, 2011). Yet few studies have been carried out to evaluate the success of the conservation nature of customary fisheries using TEK. Most indigenous knowledge studies have focussed on knowledge of structures such as classification and species distribution (Aswani and Lauer, 2010). The principles and understanding of indigenous knowledge are incomplete if we do not study this knowledge in action; it is, therefore important to combine analyses of shared cultural knowledge with research on the actual application of TEK in its local context (Menzies, 2006).

The right of Māori to participate in managing their customary fishery resources was formally recognised and legislated in Section 186 of the New Zealand 1996 Fishery Act. This chapter attempts to evaluate the state of shellfish populations in three customary fisheries reserves in Kaikōura, Rāpaki and Port Levy (Koukourārata) from a Māori cultural perspective through the use of Traditional Ecological Knowledge (TEK) of distinguished members of the three local communities. This is the first study to attempt to evaluate the state of customary fishing grounds using traditional ecological knowledge (TEK) in the Canterbury region.

5.2 Māori Traditional Institutional Arrangements for Marine Resource Management

The definition of institutions offered by Scott (1995, p 33) is instructive: "Institutions consist of cognitive, normative, and regulative structures and activities that provide stability and meaning to social behaviour." Fisheries worldwide are managed with a wide-ranging variety of institutional arrangements. Some of these institutional arrangements have evidently resulted in catastrophes while others have resulted in biological and economical achievement and consequently sustainability. Institutional arrangements are important for successful fisheries. Institutions are created by the government or communities in order to allocate scarce resources and to resolve conflicts among resource users. This first section discusses the institutional arrangements in the Māori community and how the cultural aspects shape human behaviour and actions to promote sustainable fishery.

Māori similar to other native people from all over the world have a deep sense connection to the land and sea which allows them to view the natural world with totality (Ririnui and Memon, 1997). Māori ownership of the sea was an extension of the land (Waitangi Tribunal 1992) therefore ownership was based on community relationships and social order of the society; from whānau (extended family), to hapu, a group of whānau, commonly known as sub–tribe. The size of the whānau would normally be around few hundred people, with the larger group, iwi which is made up of a few hapu (King, 2003).

Māori view the natural environment and people as one, each have its own life force (mauri) that must be respected and protected. Customary ethics and systems have been nurtured to promote the protection of resources (Marsden, 1989). Human beings have been assigned the responsibility of looking after other living things around them (kaitiakitanga). Kaitiaki is a word taken from the verb "tiaki" (meaning to safeguard, to care for; to watch over)- with the prefix "kai" signifying the doer of the action (Roberts, et al, 1995). Therefore a "kaitiaki" can be interpreted to mean a guardian and kaitiakitanga the act guardianship (Mutu, 1994). Kaitiaki are people with an active role in the management of resources based on Mātauranga (indigenous) Māori values and perspectives (Awatere, 2008). Kaitiakitanga include rules, values and principle duty humans have, to look after the well-being of the environment for the next generations (Ririnui and Memon 1997). It is strongly entrenched in the Māori way of life and is evidently visible in the laws, and code of behaviour of Māori communities. The whole principle of kaitiakitanga is customarily important to the conservation of the fisheries resources because it provides an instrument for Māori customary fishing rights to be acknowledged as well as allow Māori communities to be directly engaged in the management and monitoring of customary fishing grounds.

Māori management of fisheries includes a spiritual component which guides the resource use, and together with communally based institution ensures that fisheries are utilised in a sustainable manner. Specific fishing grounds owned and managed by hapu (sub –tribes) use their mātauranga (traditional knowledge) acquired through centuries of observation and experience of their fishing grounds. Hapu Tribal fishing boundaries were determined by natural landmarks such as rivers, hills or mountain ranges, and access rights clearly defined and understood by each member (Waitangi Tribunal, 1988).

When a certain species becomes over harvested chiefs would enforce a rāhui or temporary closure over a particular fishing area to permit the recovery of the stock. The hapu management structure was effective in restricting all forms of fishing (subsistence, gifting and trade) and integrated traditional knowledge imposed by cultural regulations.

Chiefs also would impose fishing restrictions such as tapu (spiritually based restrictions) on specific resources such as shellfish beds when required to manage and preserve stocks (Bess, 2001). Members of the hapu have great respect for the tapu and completely understand that it is a grave offence to break the tapu because one would be punished by their ancestral gods.

The exclusive rights that Māori have to their fishing grounds allows them to establish access and restrictions such as fishing gear restrictions, minimum size and catch limits, protection during breeding seasons, establish temporal (rāhui) or permanent closures (mātaitai). These Māori practices are very much the core of the modern management strategies that are used today. The key to understanding the Māori view of environmental issues is the importance of not altering mauri to the extent that it is no longer recognizable; an area being harvested must not have its essential character changed as a result of the harvest (Williams, 2006).

5.3 Use of Traditional Ecological Knowledge in Monitoring

Inspite of the huge emphasis placed on the importance of modern science and technology as the instrument for development and progress in the modern world, there is also a growing recognition of the importance of indigenous knowledge (IK) or traditional ecological knowledge (TEK) in resource management. Recently traditional knowledge systems of local communities have been increasingly studied by those concerned with conservation worldwide (for example, Berkes and Folke, 1998; Berkes, et al. 2000, 2003; Gadgil, et al.1993; Olsson and Folke, 2001; Ostrom, 1990). It has been recognised that the use of TEK in customary management practices provides an effective conservation instrument, especially in places where indigenous cultures is actively practiced (Harkes & Novaczek 2002; Hickey and Johannes, 2002).

Māori have been observing, using and interacting with their natural environment for many centuries. Cultural knowledge and values reflect a long history and relationship that tangata whenua have with a given land area, fishery, and region and signify their world view (Tipa and Tierney (2002). Cultural values are explanations of knowledge, connections to a place, and establish responsibility to a geographic area or resource (Harmworth, 1995). They can therefore determine the way Māori consider issues, make decisions, find solutions, and are important for defining goals, needs and priorities (Harmsworth 1995). Cultural indicators help to express cultural values, assess the condition of the environment from a cultural perspective, and promote a role for Māori in environmental monitoring (Tipa, 1999).

For Māori, TEK is the underlying foundation for all sustainable resource management, decision making, as well as the development of monitoring tools (Harmsworth and Tipa 2005). TEK has been used in some Māori environmental sustainability monitoring projects which include (Harmsworth (2002), Hauraki Trust Board (1999), Kowhai Consulting Ltd. (2002) and Tipa (1999), Tipa and Teirney (2002 and 2003) and Pauling (2007).

5.4 Methodology

5.4.1 Key Informats interview

Considerable TEK research in New Zealand has been based on interviews with Māori (e.g., Lyver, 2002; King and Skipper, 2006; Kitson and Moller, 2008; Moller, et al. 2009b). According to Tipa and Teirney (2003) interviews with tangata whenua are an important and effective way of gathering specialist knowledge of the traditional resource sites.

A particular advantage of the interview as a research method over questionnaires is that it permits the researcher to probe more intensely if required, gathering more data from the interviewees (Cohen, et al. 2000). Key informants are a select group of people who are especially knowledgeable or experienced about certain issues or problems and are willing to share their knowledge. In this study key informants are kaitiaki (resource guardians) and kaumatua (elders) who are respected and knowledgeable about their customary fisheries. Tipa and Tierney (2002) recommended that people like kaumatua and those who are active kaitiaki or engage in mahinga kai activities in the community are ideal candidates to be interviewed for their Indigenous knowledge of their resources.

According to Jimenez (1985), a key informant interview involves talking to persons such as community leaders who know the area and have in depth knowledge about a topic. The interview is used when written records or published documents are limited or do not exist, when information from different perspectives is needed, and when there are key informants who are accessible and have in-depth knowledge about a topic. The lack of or non-existance of indigenous knowledge records about the three customary fisheries prompted me to use key informant interviews as a tool to collect in depth qualitative information and deeper insights about community's beliefs, values, perceptions, attitudes, experiences and understanding of customary fisheries institutions for managing customary reserves**.**

I first contacted the community kaumatua (elders) and sought their consent to conduct the research in their customary fisheries. A series of informal discussions was carried out with community elders to explore their indigenous knowledge of their fisheries as well as to give me an overview of the how Māori customary management system operates within the three different communities of Kaikōura, Rāpaki and Port Levy. These informal face to face discussions ensured a free flow of ideas and allowed me to discuss as many aspects of customary reserves as possible in a very relaxed atmosphere. During the discussions I explained the purpose of the interviews and the objectives of the research.

The semi-structured interview was the main method used to explore the kaitiaki and kauamatua's Indigenous knowledge of their customary fishing reserves. A semi-structured interview is usually conducted in a face to face setting which allows the researcher to seek new insights, ask questions, and assess experiences in different perspectives**.** A list of interview questions was prepared and was sent to the kaitiakitanga/kaumatua a week before the schedule interview. The questions were intended to guide the interview and enable development of further areas of enquiry. During the interview probes or prompts were used to fill the gaps in the participants' responses to questions. There were 25 questions all together which were based on six themes: (1) Connections to history and tradition (2) Kaitiakitanga/guardianship responsibility (3) Māori marine indicators to measure the health of the marine reserves (4) Is reserve achieving its objectives? (5) How have environment changes affected the reserve? (6) General Assessment of the reserves. Questions under these themes were designed to evaluate the interviewee's cultural perspectives on the status of their customary fisheries. The themes closely follow the Marine Health Index (MHI) based on community knowledge developed by Te Tiaki Mahinga Kai (a national network of tangata kaitiaki, kaumatua, environmental managers and researchers formed to improve management of mātaitai, taiapure and rāhui. The key indicators are continuation of traditional harvest practices, changes in the taste of shellfish, changes in abundance and size of shellfish, environmental changes that affect health of fisheries.

Indigenous communities monitor the state of resource populations based on aspects of harvest such as number, size or on observations related to harvest. The questionnaires and interviews were designed to provide understanding of local knowledge regarding their customary harvest and the resilience of customary institutions that govern the management of the customary fisheries. The interviews provide the indigenous knowledge of the present state as well as the past state of the customary fisheries which is not possible to acquire through the scientific data.

Five of the six interviewed are males and 1 female. The 6 interviewees have served as kaitiaki for their respective communities for the total of 69 years and four are still serving as kaitiaki. The number of years the interviewees served as kaitiaki range from 5 to 20 years. One member of the group had also served as Honorary Fishery Officer for 22 years. All the interviewees are also regarded as kaumatua by their respective communities because of their valuable knowledge of their community. All are still taking an active role in the management of their customary fisheries. The interviewees will be referred to as kaitiaki in this thesis.

5.5 Customary Reserve Questionnaire for Customary Owners

Name of Customary Reserve:

Name of persons interviewed:

Roles: Kaitiakitanga and kaumatua

Number of years in the role:

Date of interview**:**

5.5.1 Connection to History and Tradition

1. What is the traditional association between the community and the site?

2. Does the reserve still connect you deeply to your history and tradition and tipuna (ancestors?).

Please explain:

3. How strong is this connection?

1. Very weak 2. Weak. 3. Moderate. 4. Strong. 5. Very strong

4. Do you still remember stories of the how your ancestors collect shellfish from the site

5.5.2. Kaitiakitanga / Guardianship Responsibility

5. How strongly do you feel about your responsibility of kaitiakitanga/guardianship of the marine resources within your reserve?

1. Very weak 2.Weak 3. Moderate 4. Strong 5. Very strong

6. Has there any change in the way you carry out this responsibility of kaitiakitanga?

7. How is your responsibility of kaitikitanga now different from your ancestors? Explain.

8. What are some of the difficulties that you face now in carrying out your responsibility of kaitiakitanga? Does working full time affect the way you carry out your responsibility?

5.5.3 Māori Indigenous Knowledge of the Health of the Customary Reserve

9. How abundant was the shellfish species in the past (relative assessment)

1. Insufficient 2.Slightly sufficient 3. Sufficient 4. Slightly abundant 5.Abundant

10. Are the mahinga kai species that were gathered in the past still there?

11. How did you realise that shellfish populations have been depleted and need to be protected?

12. Are there environmental indicators (tohu) that shows shellfish populations are depleted? Explain:

13. Are there land based signs that indicate the readiness for harvesting of certain shellfish species? (Example: flowering of certain plants)

14. Maori have developed a set of practical rules to protect the habitat and allow the resources to grow and flourish e.g sacks and baskets are not allowed to be dragged over the shellfish beds. Does the community still practice these conservation rules?

15. Do you notice seasonal changes in abundance and sizes of shellfish?

16. When is the best season to collect pipi, cats eyes, cockles?

17. Do you notice any difference in the taste, smell, size and colour of shellfish during this season compared to other seasons? If yes explain

18. Where do you find the highest density of mature pipi on the beach?

5.5.4 Is the Reserve Fulfilling its Objectives?

19. Can sufficient quantities of kaimoana be harvested, in season, to meet reasonable customary needs?

20. Sufficient quantities are harvested to meet customary needs (circle the best answer)

1. Never 2. Hardly 3. Sometimes 4. Most of the time 5. Always

21. Are the appearance, size, colour, smell and taste of kaimoana ‘right’ in season?

22. Have you notice changes in size, abundance of shellfish (cats eye,cockles, pipi, paua, mussels) since the customary reserve has been put in place?

5.5.5 Changes in the Reserve

23. How have changes listed below affected your customary reserve?

a) Land use:

(b) Amount of sediment

(c) Water quality

5.5.6 General Assessment of the Reserve

24. How would you describe the overall health of the reserve?

1. Very unhealthy 2.Slightly healthy 3. Healthy 4. Mostly health 5. Very healthy

25. What is your vision of the mātaitai reserve?

5.6 Kaupapa Māori Research principle

The research investigates Māori customary fisheries, values and beliefs of the community about their fishing grounds. In carrying out the interviews I adopted a philosophical approach that supports a Mātauranga Māori practice to indigenous research. Waters (2006) cited several aspects of Kaupapa Māori Research principle (KMR) that I used to guide me in interviewing the kaitiakitanga/ kaumatua as well as in all my communication with members of the three communities.

- Aroha ki te tangata (respect for people)
- Kanohi kitea (to present yourself face to face to people)
- Titiro, whakarongo, korero (look, listen, speak)
- Manaaki ki te tangata (share and host people, be generous)
- Kia tupato (be cautious)
- Kaua e takahia te mana o te tangata (do not trample over the status of the people)
- Kaua e mahaki (do not fault their knowledge)

The KMR values constantly provided the guideline on how I interact with Māori community members.

5.7 Ethical Considerations.

Research involving people must be developed ethically, more importantly when it concerns indigenous people. This research is about three indigenous communities and their customary values and belief about their fisheries. The ethical considerations of this research were considered seriously to ensure that proper procedures were followed. Ethics approval was sought and granted by the University of Canterbury Māori Research Group as well as the University of Canterbury Human Ethics Committee. Approval for the project was received on the 9th November 2011 with approval number HEC 2011/2010. The approval process involves a peer review of the entire interview process, starting from the purpose of the study, selection of the participants, intellectual property considerations as well as the provisions for the future use of interview data.

An information sheet was prepared and given to each research participant before the interview was carried out. This was done to make certain that the research participants understood the objectives of the research as well as how the information was going to be collected and utilized. The interviewees were also informed that interview data were going to be securely stored at the University of Canterbury for up to 5 years and then destroyed. The information sheet clearly stated that taking part in the interview was voluntary and participants had the right to withdraw from the interview at any time as well as their identity and the information they provided will be confidential. The promise of confidentiality was made in recognition of the sensitive nature of some of the requested information. This study was designed in such a way to prevent any potential negative influence of the research on the interviewees and therefore avoided revealing for example the precise areas where they concentrate their fishing effort. A consent form was also distributed with the information sheet for participants to sign indicating they have agreed to participate in the research.

5.8 Results

5.8.1 Connections to History and Tradition

The kaitiaki /kaumatua were asked to indicate the traditional association of their respective communities to their customary fishing ground and to rate their connection from to the site from 1-5 using 1 as very weak and 5 as very strong. The aim of these questions was to gage their attachment or relationship to their customary fishing grounds.

All the kaitiaki of the three reserves indicated that they are still very strongly connected to their customary fishing grounds (Figure 5.1). They all value the customary reserve sites because it was the site chosen by their ancestors and have not only provided them with food but it is the place that have given them their identity, history and tradition. One of them mentioned that without their customary fishing ground “they are nothing”. The strong connection to the customary fishing grounds motivates the community to protect and sustain the resources of the fishing grounds. All kaitiaki of the three reserves agreed that shellfish were more abundant in the past compared to today. Community members would only harvest what they needed and follow conservation ethics very closely for example any rocks lifted or turned should be replaced as they were.

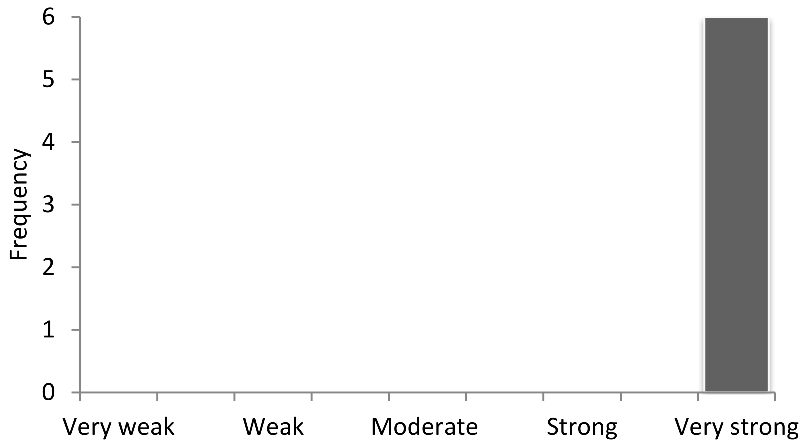


Figure 5.1: Frequency distribution of how kaitiaki rate their connection to their customary reserves (n=6)

5.8.2 Kaitiakitanga/guardianship Responsibility

Questions were asked regarding how the interviewees feel about carrying out their responsibility as kaitiaki in the modern era. They were asked to identify changes in their roles and the difficulties they face now in carrying their roles, as well as their vision of the customary reserves in the future. These questions were asked to assess how strongly kaitiaki take their responsibility as guardians of their fishing grounds and how they have adapted to serve as kaitiaki in a changing society with different socioeconomic conditions.

The kaitiaki were first asked how strongly they felt about their responsibility of kaitiakitanga/ guardianship and to rate their commitment from 1-5 using 1 as very weak and 5 as very strong. All the kaitiaki from the 3 customary reserves rated their commitment to their responsibilities as strong or very strong (Figure 5.2.). They expressed the view that they are fully committed and it is their customary duty to ensure that the customary fisheries are sustainable managed for the next generation to enjoy. On the question of whether there were any changes in the way they have carried out their responsibility as kaitiaki/guardians now compared to their ancestors. All agreed that the conditions today are certainly different from the past. They have realised that that their role has changed over the years. They not only have to ensure that their local community adheres to the customary conservation ethics, but people of different cultural grounds from outside the community also understand and observe the rules of the customary reserves. For example Asians and Pacific islanders frequently collect shellfish and have to be reminded to collect only what they are entitled to take.

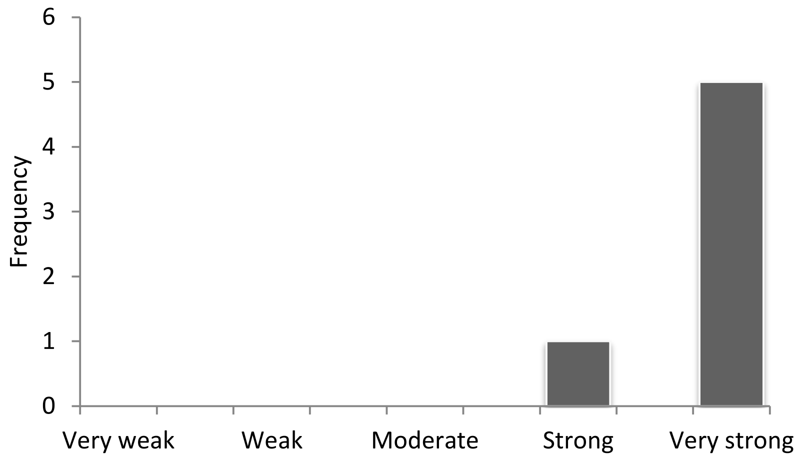


Figure 5.2: Frequency distribution of how strongly kaitiaki feel about their responsibility as kaitiaki/guardian of their customary fisheries (n=6).

Three interviewees one from Rāpaki, Port Levy and Kaikōura mentioned that today there is a Fishery legislation which determines what they do as kaitiaki. There is paper work to be done in recording catches which was not needed in the past and today they not only have to liaise with their own community but with the government as well. The interwiewees also mentioned that there was plenty of seafood in the past to cater for the demand so kaitiaki responsibility of guarding the customary fisheries was a lot easier. One kaitiaki mentioned that in the past they only made rules for their own community, now kaitiaki from different communities get together to share their experiences and try to work out rules that will work for everyone.

The interviewees were also asked, to identify difficulties they encounter in carrying out their responsibilities. The common difficulty expressed by all interviewees was that the responsibility of kaitiaki has now increased and very different from the past. They have to guard the sustainable use of the fisheries not only for their own people but from outsiders who may not understand what they are trying to achieve as a community. There is a challenge in trying to get outsiders to understand why there is a mātaitai. There is need to educate people about the need to use fisheries resources in a sustainable way. In Kaikōura for example the kaitiaki mentioned the need to educate tourist as well as the many people from outside Kaikōura who come to their fishing grounds to catch fish or collect shellfish. The Fishery Legislation has weakened their powers to effectively police their fishing grounds so they had to campaign to the Fisheries Department to get Fisheries Officers stationed in Kaikōura**.** One of the kaitiaki from Port Levy mentioned that she has moved away from the community because of other commitment and found it difficult to effectively carry out her responsibility as kaitiaki, although she still issues fishing permits. The kaitiaki at Port Levy expressed the difficulty they have in policing their reserve because it is large and isolated. One of them express disappointment that now they cannot stop a person from unlawfully fishing in the reserve as the Fishery legislation does not recognise their customary right to do that anymore. They have no powers to question, search and seize any illegal fisher but have to inform the police.

5.8.3 Māori Indigenous Knowledge of the Health of the Customary Marine Reserve.

The aim of the set of questions under the above theme was to record the kaitiaki indigenous knowledge of the abundance of mahinga kai (traditional seafood) in the past as well as to evaluate the current state of their customary fisheries and how it has changed through time. The kaitiaki were asked to assess the abundance of shellfish in their fisheries in the past and present, identify if there are seasonal changes in shellfish abundance, distinguish environmental indicators (tohu) that signified the abundance of certain shellfish as well as its readiness for harvesting, if conservation ethics are still being adhered to by Māori communities and what is the best season for collecting shellfish.

The interviewees were first asked to indicate the abundance of shellfish species in their customary reserves in the past as well as the present from 1-5 using 1 as insufficient and 5 as abundant. Kaitiaki from Kaikōura and Port Levy rated the abundance of shellfish species in the past as abundant. For the present status Kaikōura kaitiaki believe the shellfish abundance is sufficient while kaitiaki of Port Levy perceived their current status is slightly sufficient (Figure 5.3). The Kaikōura kaitiaki said their entire coastal environment was once pristine, but the increase in population and pollution as well as the economic value of some fishery resources such as paua and crayfish has decreased the abundance of these species in their fisheries. The Port Levy kaitiaki commented on how their customary fishing area was well known to Māori as the food bowl of the Canterbury region and for its tasty mussels. Rāpaki kaitiaki rated the abundance of shellfish species in the past in their fisheries as (4) slightly abundant and the present status as sufficient (Figure 5.3).

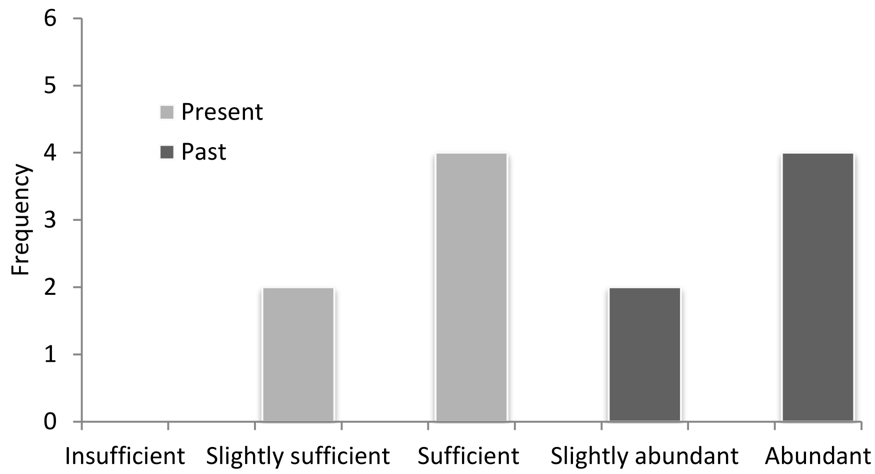


Figure 5.3: Kaitiaki assessment of the relative abundance of shellfish species in the past and present (n=6).

All 6 interviewees noted that not all shellfish that were present in the past are still there now. At Rāpaki the kaitiaki commented that there used to be plenty of cockles but not anymore and it is difficult to find kina and oysters now. In Port Levy the kaitiaki expressed their disappointment at the loss of brownshell pipi known as roroa in Māori, and the decreased abundance of cockles over the years. Paua used to be found on rocks just in front of the village, but have disappeared and there also used to be plenty of blue mussels, but these are very difficult to find now.

When asked how they realised that shellfish populations have been depleted and needed to be protected, all interviewees stated that over the years they had noticed that the size and number of shellfish were smaller and it was taking longer to catch enough for a meal. The kaitiaki of Port Levy commented that it was difficult for their community to find cockles where they were normally found and they had to go further out to collect enough for a meal. At Kaikōura the kaitiaki mentioned that the site of their rāhui was easily accessible so it was a favourite spot for collecting shellfish. The number of people collecting shellfish had increased significantly over the years and they as kaitiaki had lobbied hard with the Ministry of Fishery to get fishery officers stationed at Kaikōura to help police their fisheries.

Kaitiaki at both Rāpaki and Port Levy commented that increased silt on their customary beaches is one environmental indicator that is associated with the depletion of shellfish populations in their customary fisheries. One of the Rāpaki kaitiaki also indicated he had also noticed orange scum on the water and on the rocks which was not there before.

Māori have very strong conservation ethics. The interviewees were asked whether their community still practiced conservation ethics that allow resources to grow and flourish. The Port Levy kaitiaki revealed that their people do not strictly practice the conservation ethics that they used in the past. For example nowadays they do not say prayers before fishing as they were taught to do in the past and they now collect shellfish mostly from the beach in front of village site whereas in the past they would rotate where they harvest to allow shellfish to regenerate. In Kaikōura and Rāpaki the kaitiaki said that conservation ethics are still alive and strong in their community and it is followed to ensure shellfish populations are sustainable. For example they mentioned that community members would only harvest what they need and any rocks lifted or turned during harvesting would be replaced as they were. They still use their hands to harvest unlike some outsiders who they have seen using knives and wires which are very destructive.

All the interviewees did not notice any seasonal changes in abundance and sizes of shellfish in their reserves, but all said that most shellfish have seasonal changes in taste. They taste better in summer compared to winter. One of the kaitiaki from Rāpaki mentioned that cats eyes are bitter in winter and cockles taste better in summer. Mussels according to one kaitiaki from Port Levy are tastier in summer but not so in winter when they are brown and thinner. Kaitiaki of Kaikōura mentioned that kina are tastier in summer when the flesh is fat compared to winter when the flesh gets thinner and taste bitter. The best season for collecting shellfish for all interviewees is summer. In summer shellfish species taste better than other seasons.

Interviewees were also asked to indicate where they found the highest density of mature shellfish in their respective customary reserves. All interviewees mentioned that the lower shore of the inter tidal zone is the area where they would find larger size shellfish and in some places completely covered by water. In Rāpaki one of the kaitiaki mentioned that community members know that large adult pipi are usually densely found in the shallow subtidal zone of the beach, which is where the harvesting is done.

5.8.4 Is the Reserve Fulfilling its Objectives?

The questions were asked to evaluate if the customary reserve was fullfiling its objectives of regenerating shellfish populations and provide a kaitiaki/kaumatua perspective of the benefits of a customary reserve.

The interviewees were first asked if sufficient quantities of kaimoana can be harvested in season to meet reasonable customary needs. At Kaikōura the kaitiaki disclosed that there is enough kaimoana to satisfy the present customary needs. The kaitiaki of Rāpaki revealed that there are enough pipi and crabs but mussels, cockles and oysters are inadequate to meet customary needs. Kaitiaki of Port Levy agreed that there are generally enough mussels, cockles, paua and kina to meet customary needs, although one needs to go further out to collect enough paua and kina.

The kaitiaki were asked to rate how consistent their fisheries are meeting their customary needs now as well as in the past by choosing a number from 1-5 which best described their answer. Kaitiaki from both Kaikōura and Port Levy chose most of the time (4) while Rāpaki kaitiaki decided that sometimes (3) best described how their customary reserves were fulfilling their customary needs (Figure 5.4). In the past all kaitiaki believed that they always had enough to meet their customary needs (Figure 5.4). In Kaikōura one kaitiaki stated that the pakeha in the past had little interest in eating shellfish, but gradually started harvesting it so the numbers of harvesters increased. Kaitiaki from Rāpaki and Port Levy mentioned that their community would harvest and eat on the beach, because there were plenty to eat.

When asked whether they have observed changes in the size and abundance of shellfish since the customary reserves have been put in place, kaitiaki of Kaikōura revealed that cats eyes and paua have increased in size and abundance while at Port Levy kaitiaki indicated that cats eyes and cockles have both increased in size and abundance. At Rāpaki the kaitiaki stated that cats eyes have not changed much in size and abundance and they are not sure whether pipi populations have improved in size and abundance but indicated that the paua population had improved in size and abundance.

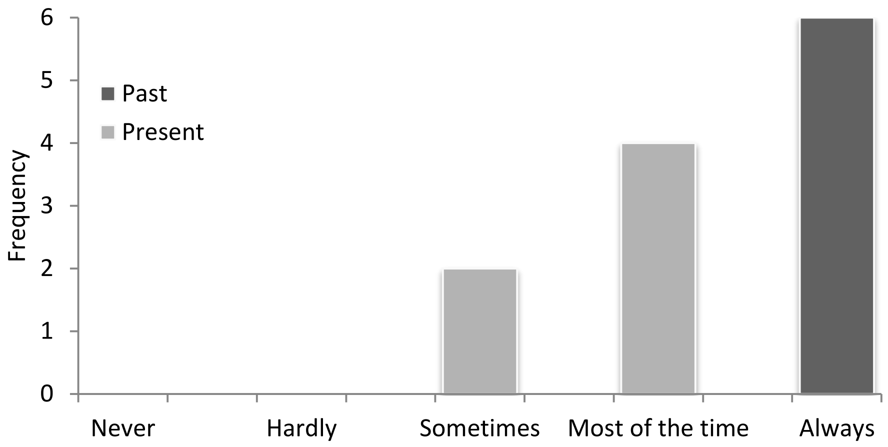


Figure 5.4: Kaitiaki knowledge of how consistent their customary reserves have been meeting their customary needs in the past as well as at present (n=6).

5.8.5 Changes in the Reserve

This section of the interview kaitiaki was questioned on environmental issues that may affect the health of their fisheries. The objectives of the questions were to gauge the interviewees' observations of effects of land use and other events that they may perceive to affect the state of their fisheries.

Interviewees were asked to describe how changes in land use, amount of sediment and water quality have affected their customary fishery. Kaitiaki of Kaikōura stated that the effect of land use activities on their fisheries is minimal because it is situated in an urban environment. They are more concerned with man-made urban pollution and solid waste that are often associated with urban sites.

The level of sediment is also minimal because the area is exposed so sediment is flushed in and out by the tides. Some of these sediments are from marine sediments being resuspended from the sea floor by wave and current action. The kaitiaki believe that water quality around their fisheries is generally good.

The Rāpaki kaitiaki described that in the past every household used to own a few cattle, now nobody owns any. There also used to be top dressing of the pastures, but it has stopped. There is still a little bit of farming going on the hills above the road, but apart from that there is very little land use. Land use effects are not as prominent now as they used to be, but rain still washes sediment from the land to sea especially during heavy rain or floods. These occur where the soil is exposed. With regards to water quality, kaitiaki believed that it has generally improved with all the homes now being connected to the sewerage system so there is no untreated sewage going out to the sea.

In Port Levy the kaitiaki explained they have no control of how the land around their fisheries is used because it is leased and is currently being used for cattle farming. Top dressing is still carried out on the farm. The kaitiaki believed that farming had certainly increased the level of sediment runoff into the estuaries and coastal ecosystem of their fisheries. One kaitiaki mentioned that the sediments found on their beach are not only from the land but from the dredging that is on-going in Lyttleton harbour. Water quality around the beach in front of the village, according to one kaitiaki seems to have improved after they fenced off the stream to stop cattle from accessing the stream.

5.8.6. General Assessment of the Reserve

Interviewees were asked to assess the general health of their reserve choosing numbers from 1-5.

The kaitiaki of Kaikōura rate the health of their fisheries as mostly healthy (4) while both Rāpaki and Port Levy indicated the health of their fisheries as (healthy (3) (Figure 5.5)**.**

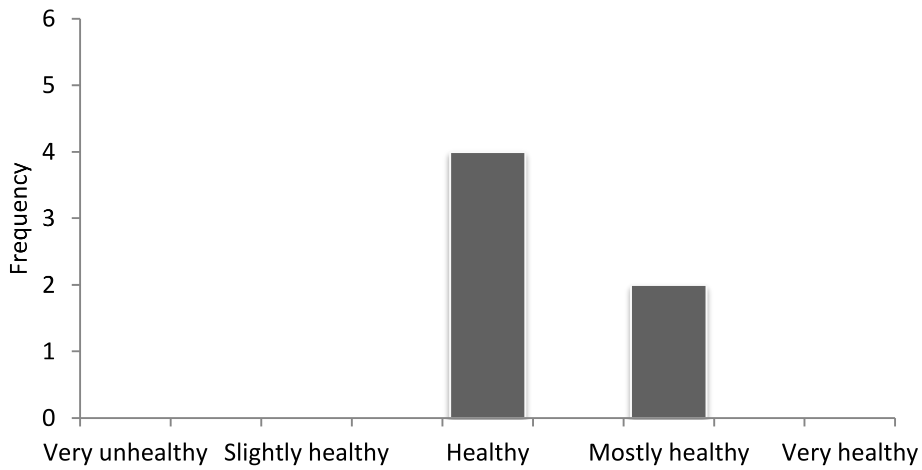


Figure 5.5: Kaitiaki knowledge of the overall health of their customary reserve.

The kaitiaki were finally asked about their visions and plans for their customary fisheries. The kaitiaki of Kaikōura revealed that they plan to extend the current life of the rāhui to another 2 years and also extend the area of the rāhui. They also plan to apply for a mātaitai reserve and have a rāhui within the mātaitai. The Rāpaki kaitiaki indicated that they are trying to extend the area of their mātaitai to cover more coastal area including part of

Lyttelton Harbour. They have the support of the wider community from Cass Bay and Corsair Bay. The size of the current mātaitai they believe is enough to cater for the needs of Rāpaki local community but not the wider community. The kaitiaki of Port Levy hope that more of their people go back to their village and settle to ensure the reserve continues. One of them stated that in recent years they have become a nomadic community and have struggled to manage their customary reserve. He sincerely hopes that the younger people of their community take an interest in the well-being of their fisheries and ensure that the fishery resources are conserved for future generations.

5.9 Discussion

Indigenous communities share a very close interdependent relationship with the natural resources they use. This relationship has helped them develop a unique and complete understanding of their surroundings. This understanding has resulted in a knowledge system, handed down from one generation to another, and used for a considerable number of activities including conservation of biological resources and environmental assessment (Brooke, 1993; Stevenson, 1996).

The TEK of indigenous people has the capability to improve fishery management by providing new information about the ecology, behaviour and abundance trends of populations of fish and shellfish, as well as determine the local environmental processes that influence fisheries resources (Johannes, et al. 2000; Valbo-Jørgensen and Poulsen 2000; Silvano and Begossi, 2002). It has been argued by some researchers that fisheries biologists would benefit by including fishermen's TEK in their research and management programs (Johannes, 1998; Haggan, et al. 2003; Drew, 2005), provided that TEK is recorded, analysed and interpreted appropriately (Huntington, 2000; Davis and Wagner, 2003).

5.9.1 Connections to History and Tradition

Indigenous societies worldwide derives their cultural identity and physical well being through intimate relationships with their natural resources (Posey, 1999; Grim, 2001; Stepp, et al. 2002). The customary resources are more than a means of meeting physical needs. They are central to the core Māori values of kaitiakitanga (ethic of guardianship), whanaungatanga (ethic of connectedness by blood; relationships, kinship), and manaakitanga (ethic of hospitality, generosity, care-giving) and to the identity of Māori as tribal people (Marsden, et al. 1992). These core values have persisted even with the loss of language and knowledge (Waitangi Tribunal 2009). As Māori's intimate cultural and historical relationships with their fishing ground increases, their sense of personal responsibility motivates them to conserve and sustainably use their fisheries allowing them to preserve their history and cultural identity. The sustainable use of their resources helps them to preserve the relationship they have with their customary areas.

In the present study all kaitiaki from the three customary reserves revealed their communities intimate connections to their customary fisheries. It is the deep and intimate connection that has inspired the kaitiaki and members of the three customary reserves of Kaikōura, Rāpaki and Port Levy to protect their customary fishing sites and preserve their cultural identity. The community's deep attachment to fisheries resources has promoted a strong sense of stewardship. According to Berkes, et al. (2000) one of the strong characteristic of community fisheries management that makes it resilient and strong is their strong sense of identity and deep relationship with their customary resources.

5.9.2 Kaitiakitanga/guardianship Responsibility

Kaitiaki must protect the mauri or life force of their taonga (treasured possession or property) to ensure it is healthy and strong. A depleted taonga presents a major task for the kaitiaki. To uphold their mana the tangata whenua as kaitiaki must do all in their power to restore the mauri of taonga to its original strength (Kawharu, 2000).

In the interviews the kaitiaki speak passionately about the work they do as guardians of their fisheries and their commitment to confront the challenges they face to restore the mauri of taonga (life force of their fisheries) to its original strength. The interview reveals their awareness of how the contemporary Fisheries legislation has changed their traditional guardianship responsibility and how they have adapted to the changes. For example kaitiaki have been working outside their community to educate people of other cultures that use their fisheries, the importance of using the fisheries in a sustainable way; encouraging harvesters to only take what they are entitled to. All kaitiaki of the three customary reserves have revealed how they have approached the pakeha members of the wider community in their area to be part of their management group. They have realised that they need the support of their wider community to be able to safeguard their customary resources. When a fishery resource is depleted and degraded, it results not only in the loss of mana, but it causes harm and grief for the kaitiaki. They deeply feel their failure as guardians and suffer with their land (Waitangi Tribunal 2009). Tangata tiaki is a powerful Māori cultural mechanism for sustaining the mauri of the rohe moana (coastal fisheries).

5.9.3 Māori Indigenous Knowledge of the Health of the Customary Reserve.

An essential feature of indigenous environment conservation is its deep historical reference to past resources changes that provide an awareness of generations of social- ecological processes and change (Kofinas, 2009). According to the kaitiaki shellfish were more abundant in their fisheries in the past compared to today. They also stated that some shellfish have disappeared from their fisheries. For example in Rāpaki cockles, kina and oysters are difficult to find and in Port Levy paua and blue mussels have disappeared. They know where exactly they used to gather these shellfish and provided some reasons why they may have disappeared. For example kaitiaki of both Rāpaki and Port Levy have associated the increased sediment in their fisheries with the depletion of shellfish populations.

The traditional conservation ethics of gathering shellfish are still strong in Kaikōura and Rāpaki but it has been revealed by one kaitiaki in Port Levy that traditional methods of shellfish gathering have not been strictly followed by some members of their community. Socioeconomic changes within communities will weaken conservation ethics with a customary foundation (Cinner, 2006). Socio-economic impact in some indigenous communities has caused a separation of its members from their land and sea resources. This has resulted in changes in lifestyle, culture and employment which has led to a declining use of custom and TEK (Ulluwishewa, et al. 2008)

It is interesting to note that Port Levy had become a nomadic community in recent years. I had observed that there were hardly any community members in the village when I first started doing my research. The reason that some Port Levy people have not adhered to the conservation ethics of gathering shellfish may be due to their separation from their customary fisheries which had resulted in the declining practice of custom.

All Kaitiaki indicated that the lower zone of the intertidal as well as the shallow subtidal area is where the highest density of mature shellfish is found and this is also where the shellfish beds are located and most harvesting is done. During my research I have observed community members of both Rāpaki and Port Levy collecting pipi and cockles in knee deep areas of the subtidal zone. Māori communities have been collecting pipi from the subtidal zone for many centuries, it is only recently that scientific research discovered that pipi also occupy the sub tidal zone. Pipi were believed to be primarily an intertidal species in New Zealand with only preliminary information implying that they also occur in large numbers in the subtidal zone (Dickie, 1986; Creese, 1988). Hooker (1995) produced the first detailed study of the progressive distribution and abundance of pipi that found that they occur in large numbers in the subtidal zone. Māori kaitiaki do not distinguish any seasonal changes in the abundance of shellfish, this may be due to the fact that they do not collect shellfish all year around to be able to distinguish seasonal changes. Their season for collecting shellfish is summer when they found that shellfish taste better.

5.9.4. Customary Reserves Fulfilling customary needs

One of the fundamental objectives of the customary reserves is to provide for the customary needs of Māori communities. Most indigenous harvesters based their assessments of trends in abundance on whether they are still collecting their customary catch from the same area and approximately the same length of time (Moller, et al. 2004). Abundance meant that they were able to harvest sufficient shellfish of good quality and in sufficient quantity from their customary reserve at any time of the year.

The success of a customary reserve will be judged by how successful it is fulfilling the customary needs. When a fishery is depleted their mauri is damaged and their role in tribal identity is compromised **(**Kawharu, 2000). For Māori communities the ability to manaakitanga manuhiri (provides and cares for visitors) is vital to marae catering. Māori take pride in their ability to provide for those who do not have, they take pride in supplying kaimoana for functions (Kawharu, 2000).

The general observation of the kaitiaki of the three reserves is that their customary fisheries have fulfilled their customary food needs. The kaitiaki acknowledge that abundance of shellfish were certainly greater in the past. They also recognised that certain shellfish had increased in both size and abundance since the customary reserve has been put in place. For example at Kaikōura cats eye and paua have both increase in size and abundance while in Port Levy cats eyes and cockles have also increase in size and abundance. In Rāpaki paua had increase but kaitiaki are not sure whether pipi have changed much. It seems that the population of pipi in Rāpaki has not experienced a dramatic decrease in abundance and size to be noticed by the kaitiaki. According to Johannes (2002) it is hard for indigenous people to detect changes in food supply if it is not depleted.

5.9.5 Changes in the Reserve due to Land Use

It is a normal procedure among many communities of traditional users to follow the condition of their resources, including monitoring any changes in the ecosystems. Their closeness and daily use of the resources allows them to observe changes on daily basis. Monitoring is either carried out by the whole community or chosen individuals, such as community stewards and elders (Berkes, et al. 2000). Where ecological changes have occurred within the lifespan of local fishers, knowledge regarding ecological transformation can be detailed and useful (Aswani and Hamilton, 2004). In the present study kaitiaki have lived and used their customary fisheries for 50-60 years, ecological changes in the customary fisheries that have occurred within their lifespan are useful in assessing the state of their fisheries. In a data less context such as the case with the 3 customary fisheries, it is vital to draw on indigenous knowledge to obtain a historical assessment of recent changes and the current status of a fishery (Johannes, et al. 2000).

While kaitiaki of Kaikōura have observed little changes in their state of fisheries from land use and sedimentation due to its urban setting, the kaitiaki of Rāpaki and Port Levy on the other hand have observed significant changes in their respective fisheries. The kaitiaki of both of these customary reserves are well aware that changes in land use have affected the status of the shellfish in their fisheries. For example at Rāpaki kaitiaki stated that every household used to own cattle and engage in some form of farming. These two activities have increased the sediment run off into their fisheries particularly during heavy rain. Once the community got rid of their cattle, minimised their farming and ceased top dressing they noticed improvement in the level of sediments being washed into their customary fisheries. They also noticed that the water quality has improved since the homes are now connected to the sewerage system. In Port Levy the kaitiaki stated that cattle farming on their land had significantly increased the level of sediment washed in their coastal waters. Recently they have fenced off areas close to the creek and have started planting trees and have noticed an improvement in the quality of water in the creek.

The kaitiaki are the chosen individuals in a Māori community to monitor the use of their customary fisheries and are well informed about the changes in the status of the fisheries. The very existence of mātaitai reserves at Rāpaki and Port Levy and a rāhui at Kaikōura is a testimony that the kaitiaki had observed that the size and abundance of shellfish in their fisheries have decreased. The longer hours and further distance they had to go out to catch enough for a meal indicated that their fisheries had lost its mauri (life principle or special nature) and needed to be protected. When local resource users detect, understand, and respond to environmental change they can effectively manage environmental resources (Aswani and Lauer, 2010).

Kaitiaki of Rāpaki and Port Levy have associated the decrease in size and abundance of shell fish in their fisheries to the increase in the level sediments found in their coastal waters. This kaitiaki perspective agrees with Voller (2006) who had done some research on the population of cockles in Port Levy and identified siltation and landuse as the most likely causes of the decrease in cockle population.

5.9.6 General Assessment of the Reserve

Māori believe that small shifts in the mauri or life force of any part of the environment through the way it is used or abused would cause shifts in the mauri of closely associated components, which would eventually affect the whole system (Harmsworth and Tipa, 2006). All kaitiaki are aware that the health of their kaimoana (seafood resources) has been affected by land use. The central belief of the Māori world view is that all parts of the environment are interrelated or interdependent. The belief in the interconnectedness of land and sea has led the two communities in Rāpaki and Port levy to manage natural resources and ecosystems in an integrated way. For example both these communities are engaged in planting trees on their land to help control the transport of sediments to their coastal waters.

The kaitiaki general assessment of their reserve took into consideration the way they have used the fisheries resources as well as how their land use has affected their resources. The kaitiaki from Rapaki and Port Levy acknowledge that their reserves are still affected by sediments from the land as well as from the landfill being carried out at Port Lyttelton and therefore have rated the general health of their reserve as healthy (3). The kaitiaki from Port Levy expressed that the health of their reserve can improve if land use effects are better managed. Kaitiaki from Kaikōura rated the health of their reserve as mostly healthy (4) and both expressed that cats eyes, paua, crayfish have all benefitted from the protection of the rāhui and have increased in size and abundance.

5.10 Conclusion

The result of the cultural assessment of the customary reserves indicated that the reserves are conserving shellfish to meet the demands of the community customary needs. The kaitiaki acknowledge that the abundance of shellfish were certainly greater and larger in size in the past. They also recognised that certain shellfish had increased in both size and abundance since the customary reserve has been put in place. The kaitiaki are aware that their land use activities have increased the amount of sediments being transported into their fisheries

CHAPTER 6: General Discussion

6.1 Introduction

The use of customary fisheries management has been advocated by many (Johannes, 1981; Akimichi 1984; Chapman, 1985; Ruddle, 1998 and Berkes, 1999) to be a more effective way of managing inshore fisheries resources. Yet very few studies have been carried out to determine whether it is actually successful in conserving and promoting the sustainable use of fisheries resources. According to Cinner and Aswani (2007) the success of customary fisheries management systems in achieving conservation goals within the biological literature, are mixed and research conducted so far is limited. Much has been written about the potential benefits of documenting and applying Traditional Ecological Knowledge (TEK) in scientific research and resource management, but studies of its practical application is limited. In New Zealand there are only a few examples of consistent monitoring by Māori groups of customary sustainable harvest of a species. Most examples involve a science agency working with a Māori group to identify the condition of species populations and sustainable baselines (Harmsworth and Tipa, 2006).

This thesis has provided the first evaluation of the effectiveness of customary management of shellfish in the Canterbury region using both the scientific and TEK or cultural methods of assessment. Three species of shellfish (pipi, cats eye and cockles) which were traditionally important food to Māori communities were studied and analysed in three customary Māori reserves.

6.2 Pipi (*Paphies australis)* at Rāpaki Mātaitai Reserve

The results of scientific research indicate that abundance of pipi was significantly greater at the customary reserve at Rāpaki compared to the non-reserve site at Corsair Bay. The density and size of pipi increased at the lower 40 m distance at Rāpaki reserve during the entire survey while there was significant evidence of decreased abundance and density at the lower 40 m shore distance in the non-reserve site at Corsair Bay. This difference could be due to the silt/clay sediment found on lower shore of Corsair Bay.

There was also significantly higher abundance of large harvestable pipi (>40mm) at Rāpaki, in contrast at Corsair Bay there was an obvious absence of the harvestable pipi (> 40 mm).

The lack of harvestable size pipi at Corsair Bay may be attributed more to environmental factors than harvesting pressure.

There was a significant seasonal change in abundance of pipi at both the reserve sites and non-reserve sites. The abundance increased significantly during summer. Very little study has been done to identify seasonal changes in abundance of shellfish in New Zealand. The present study suggests that increased in abundance during summer was due to recruitment as there was an increase in juveniles (< 25mm).

In spite of the customary take, the highest density of pipi found at the harvesting site at Rāpaki reserve was significantly high (4968 m^2) compared to (2441 m^2) at the non-reserve site at Corsair Bay. The percentage of harvestable pipi at the reserve site (44%) was also significantly higher than the non-reserve site (22%). This study found that pipi in Rāpaki had distinct habitat segregation based on size. Juvenile pipi occupied the upper 20 m shore distance from the top of the shore while adult pipi were restricted to the lower intertidal and subtidal zones. This finding agrees with earlier studies in the North Island by (Hooker, 1995; Grace, 1972 and Jones, 1983).

The condition index of pipi at the reserve site was higher than the non-reserve site at the 20 - 30 m from the top shore. At the 40m distance condition index at Corsair Bay was higher than Cemetery beach. This study suggests that these differences were due to the variations of the slope of the beach at the two sites. At Corsair Bay the 40 m shore distance would be subtidal while at Cemetery beach it would be still in the lower inter -tidal area. Pipi at Corsair Bay therefore were exposed to more food supply than pipi at Cemetery beach. In his research research in the North Island Hooker (1995) found that subtidal pipi have higher condition index than intertidal pipi due to increased food supply.

The cultural assessment (TEK) by the kaitiaki of Rapaki indicated that they have not noticed any change in the population of pipi over the years, but there were enough pipi to meet their customary needs. According to Moller, et al. (2004) traditional monitoring observers are more likely to notice unusual rather than average patterns and occurrences. The present study agrees with Moller. The cultural assessment of the reserve by the kaitiaki indicated that the pipi population within the reserve is sustainable and healthy and the overall general health of the reserve as healthy. From this information it appears that the population of pipi are sustainable at the Rāpaki reserve.

The kaitiaki have observed changes in their reserves over the years and most of these changes have been acknowledged as caused by their land use and dredging at Port Lyttleton. The community have showed they have improved the management of their land use by removing cattle from their land as well as limiting farming. They have also publicly voiced their concern to Christchurch City Council about the increased siltation in their fisheries as a result on going dredging at Port Lyttelton.

Rāpaki site is special in terms of the pipi population. It is the only site in the Canterbury region where pipi is found in such quantity. Māori like many indigenous people choose their settlement sites because of the availability of food **(**Tipa and Tierney, 2003). Rāpaki therefore must have been chosen as a site of settlement because of the abundance of seafood.

The scientific research found that abundance and density of pipi increased towards the lower shore and adult pipi of harvestable size were dense in the subtidal areas of Cemetery beach. The Māori community through their TEK of their customary fisheries knew that pipi of harvestable sizes occupied the subtidal areas of the Cemetery beach because that is where they have their pipi beds and where harvesting is carried out. As indicated earlier, science only recognised that pipi occur in large numbers in the subtidal zone recently Dickie (1986) while Māori have been harvesting pipi from the subtidal areas for a few hundred years.

6.3 *Turbo smaragdus* (cats eye)

The population of cats eye was scientifically evaluated in the three customary reserves, in Kaikoura, Rāpaki and Port Levy. The scientific study indicated that abundance and shell lengths of cats eye were higher in the reserve sites compared to non-reserve sites. The reserve sites also had more adult and harvestable cats eyes than the non-reserve sites. The hypothesis that abundance, shell lengths, adult population and harvestable sizes would be higher in the reserves compared to non-reserves was again proven to be correct. Smaller cats eyes are able to satisfy their nutritional needs at higher shore level by feeding on micro-algae and diatoms, larger Turbo on the other hand with higher energy requirements need to feed in areas of greater food availability (Robinson, 1992). This may explain why larger *Turbo* were more abundant in the low intertidal shallow subtidal areas of reserve and non-reserve study sites.

The cultural assessment (TEK) by kaitiaki of both Kaikōura and Port Levy suggest that cats eyes in their reserves have increased in both abundance and size. Kaikōura kaitiaki indicated that the number of large cats eye has greatly increased over time. This assessment agrees with the present scientific findings. At Kaikōura, Whakatu and Avoca reserve sites, cats eyes were significantly more abundant and had more large adults compared to non-reserve sites**.** Earlier research by Robinson (1992) also found that densities of turbo at Whakatu were greater compared to the other sites she studied. This suggests that Whakatu may naturally have a better environment condition for cats eyes compared to other sites she studied**.**

At Port Levy cats eyes at the Pa village reserve site were significantly more abundant and had more large harvestable adults than the non-reserve site. The kaitiaki of Rāpaki indicated that cats eye in their reserve has not changed when compared to what was perviously. The scientific assessment found that in Rāpaki, the site at Aunties beach had more cats eye and were of a larger size than the non-reserve site. Cats eye is not a popular food today as was in the past and is not part of the food that would be used in a customary hui and tangi feast or gathering. This could explain why kaitiaki could not ascertain whether there is a change in population size and abundance.

Scientific study found that abundance was significantly higher in summer compared to winter. The cultural assessment (TEK) did not indicate any seasonal differences in abundance. As mentioned in Chapter 5 this could be due to the fact that Māori communities collected shellfish mostly in summer so harvesters would not be able to make comparisons between winter and summer. Māori do not harvest cats eye in winter because they suggest it taste bitter.

Scientific findings also indicate that *Turbo* shows a vertical size gradient with juveniles occupying the upshore and larger adults in the lower shore. Large harvestable adult cats eye densely populate the lower shores because there is greater food availability. The TEK of kaitiaki indicated that Māori do know that adult cats eye occupy the lower zones of their intertidal reserves and therefore concentrate their harvesting of cats eye on the lower shores.

6.4 Cockles: Port Levy (Koukourarata mātaitai)

The scientific research showed that cockles at all reserve sites had higher density, significantly more adult and harvestable sizes as well as a higher condition index than the non-reserve sites. The cultural assessment by the kaitiaki of Port Levy indicated that the size and abundance of cockles in their mātaitai reserve have increased during the last few years and there are enough cockles to meet their customary needs. This assessment agrees with

(Voller 2006) which indicated an increase in the harvestable size, but stocks were not increasing due to lack of recruitment. The present scientific findings study supports this.

Kaitiaki of Port Levy believed that the decrease in the abundance of cockles over the last fifteen years was due to the increased sedimentation of their fisheries caused by cattle farming on their land. This assessment agrees with the scientific study by Voller (2003), where siltation and changed in land use were identified as possible factors for limiting growth of cockles. The scientific research found that large harvestable cockles increased in abundance and size at the lower intertidal areas of reserve as well as non-reserve sites. TEK of the Port Levy kaitiaki agrees with this finding. The customary shellfish beds of the Koukourarata community were found on the lower shore of their fishing grounds.

6.5 Customary Reserve is it Conserving Shellfish Population?

The question whether customary management can achieve conservation objectives has become a topic of debate when discussing the role of customary fishery management in the modern conservation context. One of the questions the present study attempted to answer is whether the customary reserves are conserving shellfish populations. Some features of customary and western conservation ethics overlap, despite the fact they are often practiced differently (Cinner, et al. 2007). This does not mean that indigenous communities do not want, understand or practice conservation, but their methods may differ in some way from those of Western science and even among indigenous groups (Berkes, 1999; Martello, 2004). There is a need for conservation programs to represent a wider view of the livelihood of local community knowledge and interest (Berkes, 2004).

The Customary fisheries closures practised by indigenous community are generally temporary compared to the permanently closed marine reserves promoted by western science and conservation groups (Roberts, et al. 2003; Russ and Alcala, 2004). It has been discovered that strict permanent closures, applied by conservation organisation in communities that traditionally use temporary closures, are poorly observed because permanent no take closures do not suit the customary practice of harvesting a closure after a certain period of time. (Cinner, et al. 2003). In New Zealand rāhui and tapu were temporary closures imposed at species level to allow it to be reserved, or build up after being depleted. For Māori sustainability demands maintaining stewardship (kaitiaki) over land and fishery resources, therefore setting aside land and sea resources for preservation purposes separate Māori from their stewardship responsibilities (Roberts, et al. 1995). Customary management systems based on the local understanding of ecosystem developed by trial and error have certain similarities to adaptive management (Berkes, et al. 2000). Just like scientific management they may not always be effective in conserving resources (Gunderson and Holling, 2002). In some cases, customary management systems have been successful at meeting both conservation goals (increasing size and abundance of target species) as well as community goals (increasing harvests or providing enough catch for feast), with very high level of observance from community members (Evans, et al, 1997; McClanhan, et al. 1997; Aswani and Hamilton, 2004; Cinner, 2006). The present study attempted to assess the conservation abilities of the customary reserves by the use of TEK and science. Through TEK the kaitiaki are able to compare the state of the shellfish now with what it was in the past and are also able to evaluate if the shellfish are meeting their customary needs. The result of assessment through the use of TEK therefore indicated that their customary reserves are conserving shellfish to meet the demands of the customary needs. The scientific study though cannot conclude that the reserves are conserving shellfish because there is no shellfish population data to make comparisons with. The conservation issue therefore is judged by the perspective of the two different types of knowledge. While cultural perspective indicates that the reserve is conserving shellfish the scientific perspective on the other hand is inconclusive because of the lack of data.

6.6 Use of TEK and Science to Monitor Customary Reserves

Combining TEK with western science is a relatively new technique in NZ fisheries research (Maxwell, 2007). Ecological monitoring programs that draw on local knowledge, as well as science based indicators have been successfully adopted in Canada (Berkes et al 2009). The two ways of knowing, scientific and TEK are potentially complimentary (Berkes, et al. 2000). Local knowledge combined with specialised scientific knowledge is believed to be more valuable than either knowledge alone in identifying reality (Christie and White, 1997).
The combination of scientific information from many places over short periods and TEK information from long periods at specific places complement each other for improved environment monitoring (Moller, et al. 2004; Berkes, 2008). This study has shown that TEK can complement science because it provides a historical perspective of shellfish populations that are site specific as well as changes that affect the population. The lack of baseline data of the three customary reserves from the periods prior to its establishment makes it difficult to

make scientific population comparisons and identify any changes in abundance and sizes of shellfish in the reserves. TEK provides basic information on the abundance and sizes of shellfish population in the past as well as the present which makes it possible to assess changes and make comparisons.

Scientific study can help correct possible problems with TEK, including non-random sampling problems which may arise from traditional population monitoring, providing data from larger areas, providing a study of causation, and establishing the general nature of a population distribution (Moller, et al. 2004). Māori TEK often lacks some important components of the biology and ecology of shellfish they harvest. For example knowledge of broadcast spawning and planktonic larval dispersal is needed for optimal management and this expert knowledge can be provided by fishery biologist. This knowledge can be integrated into indigenous knowledge frameworks and help the understanding of population dynamics.

The TEK system does not have the same influence and strength as conventional scientific knowledge because of its informal and oral character (Gerhardinger, et al. 2009). In New Zealand it is difficult to convince regulatory agencies and competing users of fisheries resources (recreational and commercial users) about the benefits of community-based fisheries management based on anecdotal evidence alone. Collecting scientific data showing increased abundance, size and density of targeted species are more convincing and demonstrates that community-based fisheries management's is working. For example recently the Department of Fisheries request the Māori Community of Kaikōura to produce a report of the status of the rāhui to help them make a decision on the extension of the rāhui for another two years.

6.7 Community Monitoring Importance and Benefits

Given the potential value of TEK for improving the fisheries management, especially when integrated with scientific knowledge, its loss through change in cultural behaviour and thinking is a cause for concern (Johannes, et al. 2000). In the present study kaitiaki have expressed concern about the loss of traditional customs and knowledge due to modern education and development. The present study suggests that active community monitoring of customary reserves by use of TEK is one way of retaining the use of cultural knowledge that is in danger being lost.

According to Harmsworth, et al. (2008) Māori should monitor their own environment where they have a relationship, to safeguard and manage natural resources for future generations as part of their own responsibilities and for community wellbeing. The need to monitor comes from their responsibilities such as whakapapa (ancestral lineage, genealogy) kaitiakitanga (exercise guardianship) and tikanga (customary values).

Involving Māori communities of Kaikoura, Rāpaki and Port Levy in scientific monitoring has potential benefits for the communities. Some of these benefits include;

- Local people gain an understanding of the scientific method of study and allow them to compare it to their own understanding of their resources. Science monitoring helps to fill in the gaps in their understanding of ecosystems. It can build partnership for the cooperative process of creating and sharing knowledge.
- It can build trust respect and understanding between local people and science agencies involve in the monitoring like Universities and National Institute of Water and Atmospheric Research (NIWA), fishery officers or Department of Conservation. Repeated interactions between the two groups allow them to get to know each other as individuals and develop their respect of each other's viewpoints. It may help to improve relationship between kaitiaki and fishery officers
- The direct involvement of community in monitoring would increase the likelihood that monitoring results would be communicated back to and throughout the community and used for management decision making.
- Community monitoring can be a community building exercise. It allows community to reconnect and learn together in a place they are strongly connected to.

The active involvement of local people from the three communities in monitoring their customary mātaitai and rahui reserve on a regular basis to measure whether the goals and aspirations for their customary reserve are being achieved is critical. The communities should be encouraged to monitor their customary reserve using both the scientific methods as well as cultural method. Involving local communities in monitoring by using their own monitoring methods, as well as making them participate in partnership with scientific monitoring is highly likely to lead to more attention on the results and changing harvest practices (Moller, et al. 2004).

The State of Takiwa report by Pauling, et al. (2007) in the Avon-Heathcote Ihutai Estuary developed by Te Rūnanga o Ngai Tahu was one of the first to involve the Māori community in monitoring and reporting on environmental and cultural change from a cultural perspective. A second report was carried out in 2012 which closely followed the 2007 report and provided an indication of the post-earthquake state of these waterways in relation to Ngāi Tahu values. The State of the Takiwā monitoring method was designed by Ngāi Tahu to enable tangata whenua to gather, store, analyse and report on information relevant to the cultural health of waterways within their Takiwā (tribal areas). The methodology takes into account Ngai Tahu cultural values such as mauri and mahinga kai (food gathering places) and integrates mātauranga Māori (Māori knowledge) and western science. The range of assessments performed attempts to capture key cultural values and indicators of environmental health, especially those important to mahinga kai (food gathering) and other cultural activities (Pauling, 2008). When compared with the 2007 study the 2012 results suggest that the catchment is in a similar state of cultural health. In other words the cultural values have not improved as the overall assessment suggests the estuary sites are in a poor state.

The State of the Takiwā methodology as used in the 2007 and 2012 can be adapted to monitor the state of fisheries in the three customary reserves of Kaikōura, Rāpaki and Port Levy. The cultural indicators that allow iwi/hapü to assess the cultural and biological health of their customary fisheries must be discussed and agreed upon by the kaitiaki and kaumatua of the three customary reserves. Māori have traditionally used cultural indicators to measure or indicate the change in environment. Monitoring of customary reserve using TEK is an ideal way to keep alive and transfer the TEK and traditional practices to future generations.

Examples of involvement of communities in scientific monitoring include the Hauraki Gulf as well as in Pauatahanui Inlet in Wellington. Both these examples involve local community scientifically monitoring shellfish population in partnership with Ministry of Environment and NIWA. Dr Chris Hepburn at the Otago University with a group of researchers has provided local communities around Otago and Koukourarata with scientific information about the population of fish species found in the reserves. The scientific assessment provides important information about the status of the fisheries which can be used to improve the management.

6.8 Management Issues

One general finding from this thesis research is that the customary reserve sites had higher shellfish abundance; individuals were larger and there were more large harvestable adult shellfish in the population. Also shellfish had a higher condition index than corresponding non-reserve sites.

The customary mātaitai reserve is different from a no take marine reserve because it allows Māori community to harvest shellfish for their customary purposes. In spite of the customary harvest, the shellfish populations in the reserves are still in a healthier and more sustainable than the non-reserve sites. More importantly, the scientific study found a higher percentage of harvestable pipi, cockles and cats eye at Kaikōura, Rāpaki and Port Levy which suggests that customary harvesting is sustainable. The lack of recreational shellfish harvesting data from non-reserve sites as well as the unavailability of customary take from reserve sites does not make it possible to compare the level of harvesting between reserve and non-reserve sites.

According to Berkes (2009) an indigenous community often conserves resources based on a number of objectives, including sustainable use and livelihood needs, cultural value, self-governance, economic development as well biological conservation. From the cultural assessment it appears that the mātaitai reserve has allowed the three communities of Kaikōura, Rāpaki and Port Levy to harvest shellfish in a sustainable way, provided them with their livelihood needs and continued to provide them with cultural value. From the cultural perspective the customary reserves have created incentives for resource conservation. The three communities' whole cultural identity depends on the fishery reserve being able to provide kaimoana for their customary needs. The three communities uphold their mana through the prestige of being able to provide kaimoana for visitors to their hapu. From the cultural perspective the cultural identity that the reserve provides has created strong incentives for resource conservation.

This thesis research suggests that the three customary reserves are fulfilling their objectives and therefore are successful. The reserves have conserved enough shellfish to satisfy the cultural needs of the three communities. Although customary management systems may not be created for conservation in a Western scientific sense, in some cases it leads to sustainable resource stewardship (Cinner, et al. 2005; Aswani and Sabetian, 2009).

6.9 Recommendations

It is recommended that three communities carry out regular cultural and scientific monitoring of their customary reserves to monitor their performance and progress in achieving their desired cultural and ecological goals. While results of cultural monitoring are kept within the community, it is essential that information on scientific monitoring is available to the Ministry of Fisheries as well as all interested stakeholders**.** Monitoring the reserve using TEK and science is needed to monitor the general status of population of the fisheries as well as the customary harvest. According to Tipa et al. (2006) the sharing of TEK within indigenous groups is necessary requirement for the incorporation of that knowledge in community resource management. Problems associated with the generation and sharing of TEK have been well documented. TEK is often privileged knowledge, not available to wider indigenous group for comments (Natcher and Hickey, 2002). According to Tipa et al. (2002) this issue need to be addressed by indigenous groups and discussed with co-management partners and suitable processes negotiated. From an indigenous point of view the sharing of information must involve empowerment, equal partners and the recognition of their indigenous status Tipa, et al. (2002).

These three customary reserves generally lacked the linkages to Non-Government Organisations (NGO) and science organisations (universities), conservation (Department of Conservation) or science providers (NIWA), which hinders their capacity to draw upon resources or benefit from scientific insights. As mentioned earlier Port Levy has benefitted from its relationship with Otago University. This study recommends that more efforts be made to foster long term partnership with science organisations to help the three communities scientifically monitor their customary reserves.

6.10 Conclusions

Do the reserves biologically conserve resources? Scientifically there is not enough data to answer this question. Further research is needed to (1) investigate or monitor the shellfish population regularly over a period of time (2) monitor the harvest of shellfish for customary purposes. The present study has provided the baseline data that can be used to compare with future findings. Monitoring of customary reserve sites at regular intervals over a number of years will help to gain an understanding of the natural temporal and spatial variations in shellfish population, which will help determine whether customary reserves are conserving shellfish populations.

Scientific and TEK are different in their approach to monitoring population however they should be seen as alternative views of expertise that compliment rather than contradict each other (Moller et al. 2004). The use of TEK to assess the customary resources brings out the social aspects of management that cannot be assessed in a scientific study. The present study found that there was close agreement between information from TEK and scientific study which indicates that the two ways of knowledge can be used together to monitor the state of population in a customary resource**.** The use of TEK and science to monitor populations can help co-management for sustainable customary harvest by local communities of Kaikōura, Rāpaki and Port Levy.

Customary reserves like mātaitai are the preferred option to manage inshore fisheries by many Māori communities because the management program builds upon their local cultural conservation ethics which the community members are familiar. Customary Institutional Governance is still strong and there is a strong sense of community ownership. The Māori TEK, cultural values and customary practices have the potential to compliment science and contemporary management practices and enhance the effective management of inshore fisheries.

Customary fisheries management systems offer New Zealand an effective approach to manage its inshore fisheries. Government organisations like the Ministry for Primary Industries need to understand the conservation ethics of Māori and build on them. Fisheries management that build on integrating the knowledge and traditions of local people, are more likely to be successful than rules and regulation imposed by central administration (Cinner and Aswani 2007).

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Appendix 1: Pipi Preliminary Survey Results

1.1 Abundance

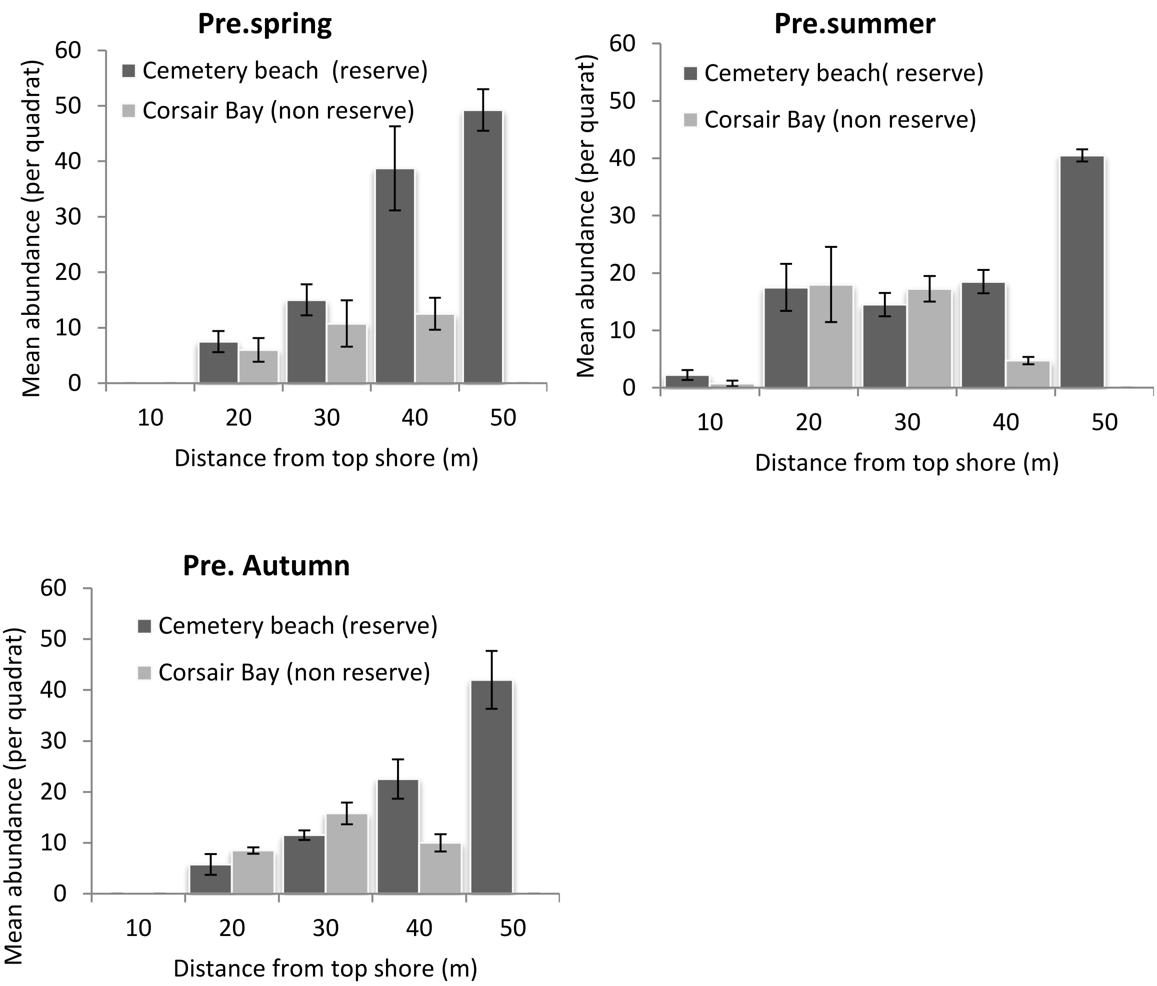


Figure A 1.1: ***Paphies australis*** **mean abundance per replicate (± s.e) collected at different shore distances from Cemetery beach (reserve) and Corsair Bay (non-reserve) during the preliminary surveys in spring October 2010, summer December 2010, and autumn April 2011.**

Table A 1.1: Result of 1 way ANOVA for mean population abundance at different shore distances in the reserve and non-reserve site during the spring preliminary survey. (Df, degrees of freedom; MS, mean squares; P, probability level; NS, non-significant; S, significant).

Source of variation	df	MS	F	P	significance
Shore distances: 20m Error	1 6	4.5 16.5	0.27	0.620	NS
30m Error	1 6	36.1 50.5	0.72	0.429	NS
40m Error	1 6	1378.1 131.6	10.47	0.017	S

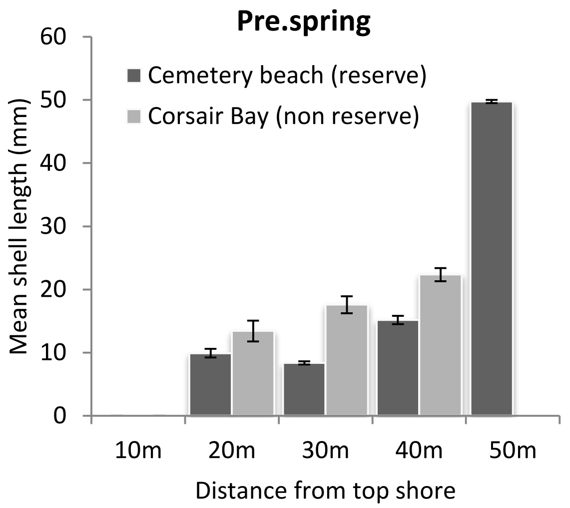
Table A 1.2: Result of 1 way ANOVA for mean population abundance at different shore distances in the reserve and non-reserve site during the summer preliminary survey. Abbreviations as in previous table.

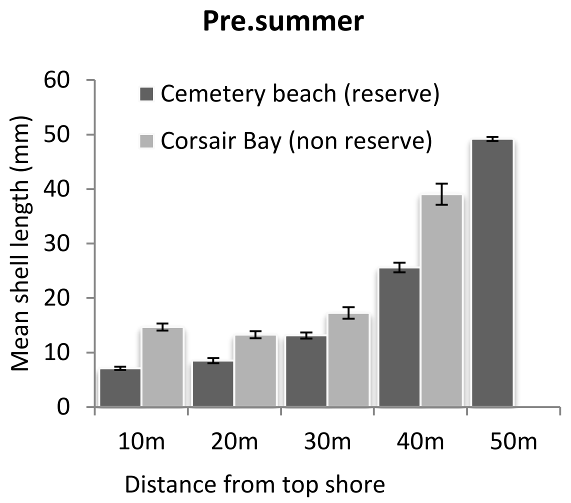
Source of variation	df	MS	F	P	significance
Shore distances: 20m Error	1 6	0.5 119.2	0.0041	0.950	NS
30m Error	1 6	15.1 18.3	0.826	0.398	NS
40m Error	1 6	378.1 8.9	42.209	0.001	S

Table A 1. 3: Result of 1 way ANOVA for mean population abundance at different shore distances in the reserve and non-reserve site during the autumn preliminary survey

Source of variation	df	MS	F	P	significance
Shore distances: 20m Error	1 6	15.1 9.3	1.63	0.249	NS
30m Error	1 6	36.1 10.9	3.30	0.119	NS
40m Error	1 6	312.5 35.5	8.80	0.025	S

1.2: Shell Lengths





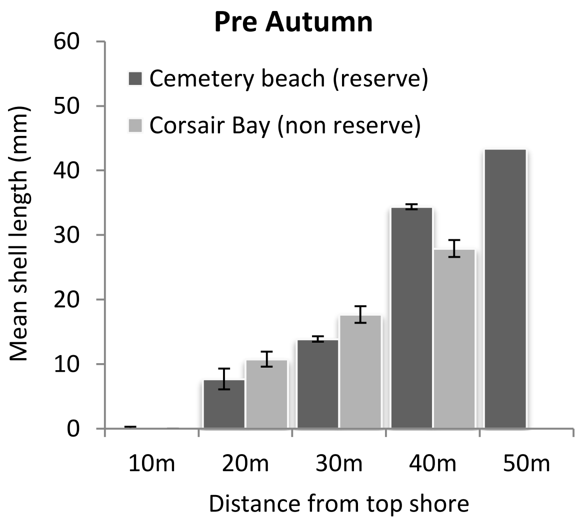


Figure A 1.2: Mean shell lengths of pipi (*Paphies australis)* at Cemetery beach (reserve) and Corsair Bay (non-reserve) during the preliminary surveys *(± s.e.)*.

Table A 1.4: Result of 1way ANOVA for average total shell lengths at the Cemetery beach and control site at Corsair Bay during the preliminary surveys.

Source of variation	df	MS	F	P	Significance
Pre.spring					
Reserve & non reserve	1	158113	0.22	0.662	NS
Error	4	713096			
Pre.summer					
Reserve & non reserve	1	20756	0.07	0.803	NS
Error	4	291413			

Pre.autumn Reserve & non reserve Error	 1 4	 458161 1650331	 0.28	 0.626	 NS

1.3: Condition Index

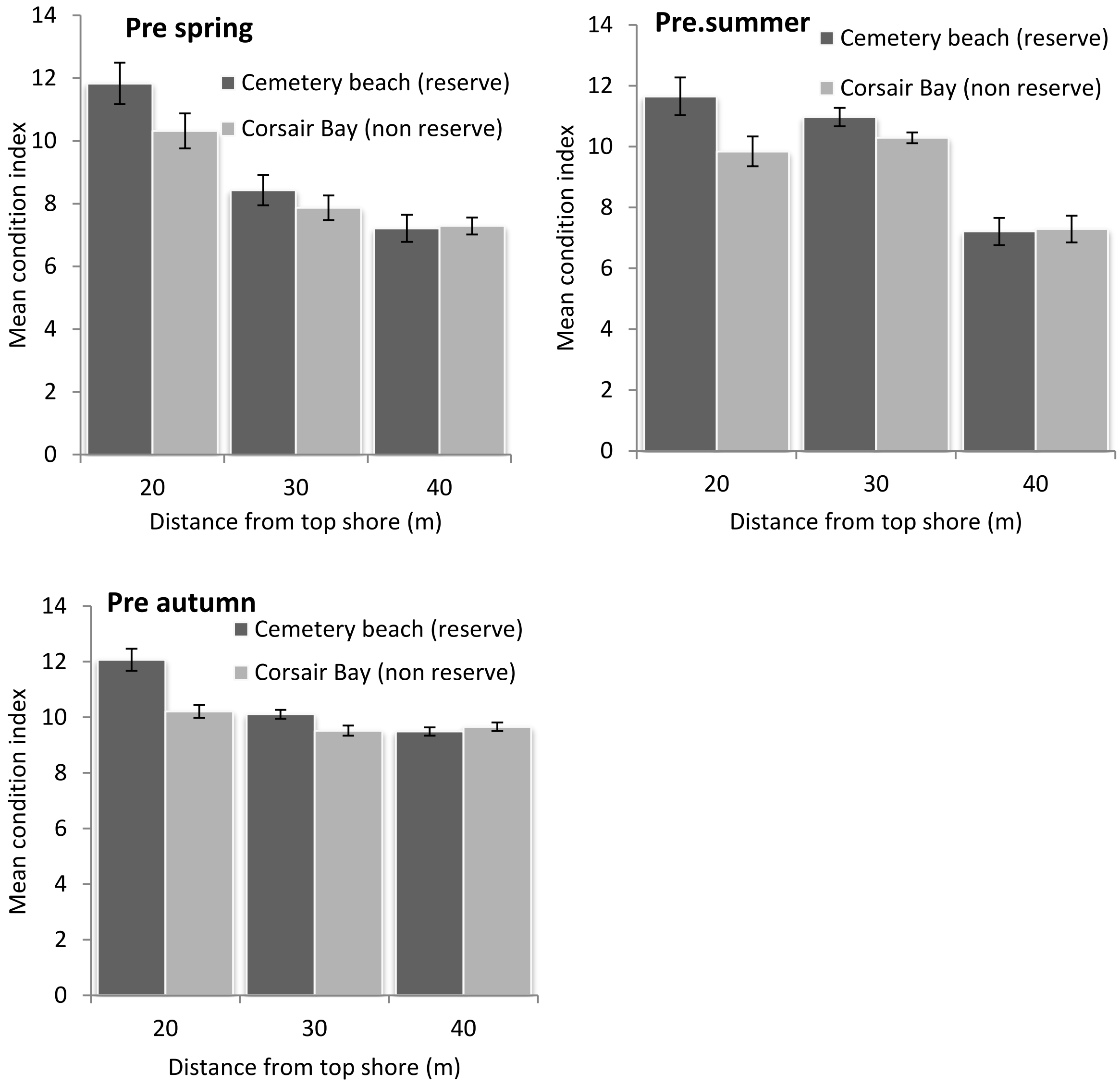


Figure A 1.3: Mean condition indices (± s.e) at the 20m, 30m and 40m shore distances during the preliminary surveys in spring October 2010,summer December 2010, and autumn April 2011

Table A 1.5: Result of 1 way ANOVA for pipi condition index at the 20m 30m and 40m shore distances at Cemetery beach and Corsair Bay control sites during the spring preliminary survey.

Source of variation	**Df**	**MS**	**F**	**P**	**significance**
Shore distances: 20m Error	 1 28	 17.10 5.55	 3.08	 0.090	 NS
30m Error	1 28	2.35 2.88	0.82	0.374	NS
40m Error	1 28	0.05 1.95	0.07	0.876	NS

Table A 1.6: Result of 1 way ANOVA for pipi condition index at the 20m, 30m and 40m shore distances at Cemetery beach and Corsair Bay control site during the summer preliminary survey

Source of variation	**Df**	**MS**	**F**	**P**	**significance**
Shore distances: 20m Error	 1 28	 24.66 4.71	 5.24	 0.030	 S
30m Error	1 28	3.47 0.90	3.85	0.060	NS
40m Error	1 28	0.19 1.93	0.10	0.755	NS

Table A 1.7: Result of 1 way ANOVA for pipi condition index at the 20m, 30m and 40m shore distances at the Cemetery beach (reserve) and Corsair Bay (non-reserve) during the autumn preliminary survey

Source of variation	**Df**	**MS**	**F**	**P**	**significance**
Shore distances: 20m Error	 1 28	 25.95 1.63	 15.90	 0.001	 S
30m Error	1 28	3.75 0.53	7.01	0.013	S
40m Error	1 28	0.02 1.58	0.01	0.908	NS

1.4: Adult and Juveniles

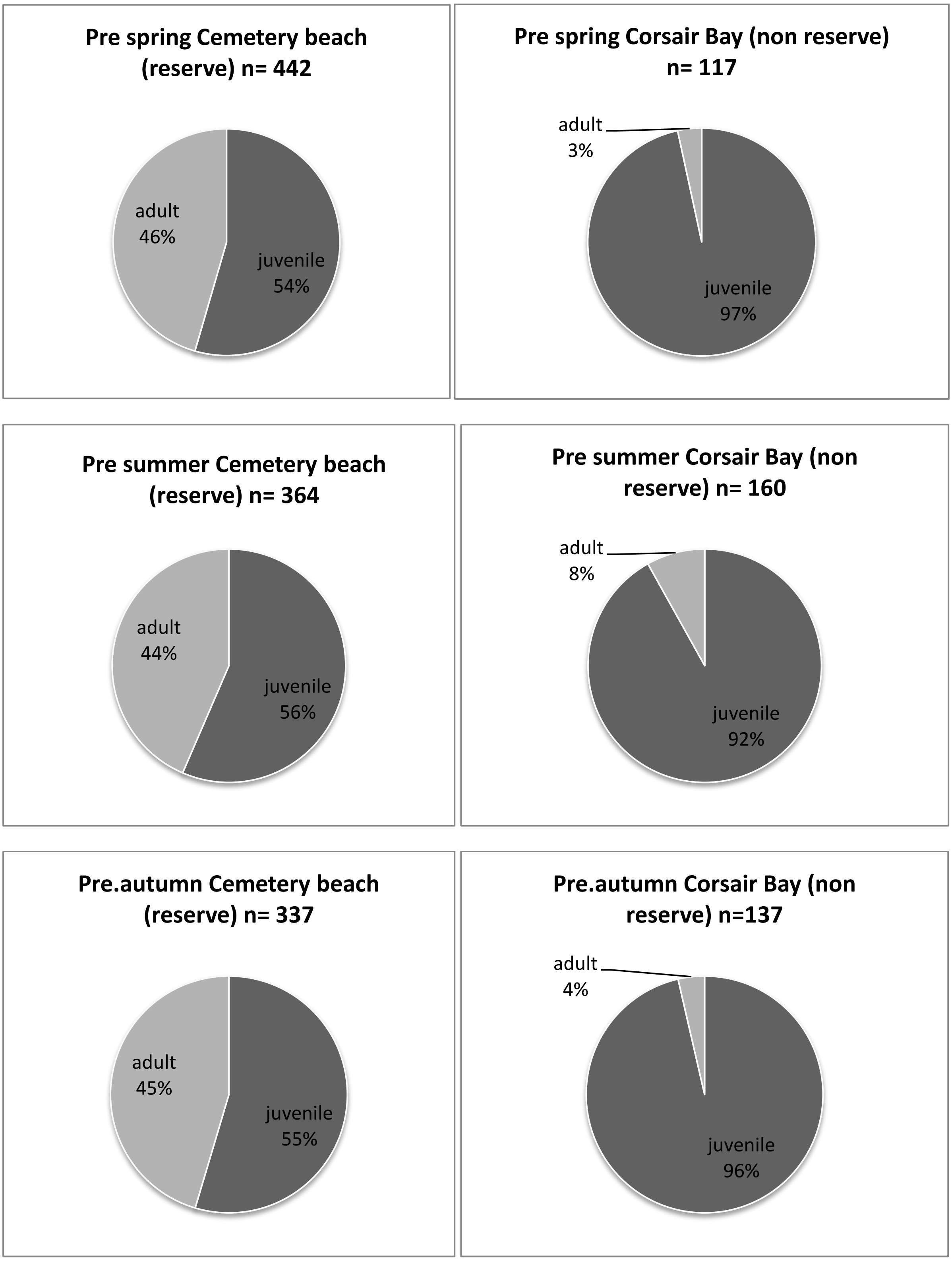


Figure A 1.4: Percentage of juvenile and adult population (harvestable size) at the Cemetery beach and control site at Corsair Bay during the preliminary survey spring October 2010,summer December 2010,and autumn April 2011.

Appendix 2: Cockles Preliminary Survey Results

2.1 Abundance and density

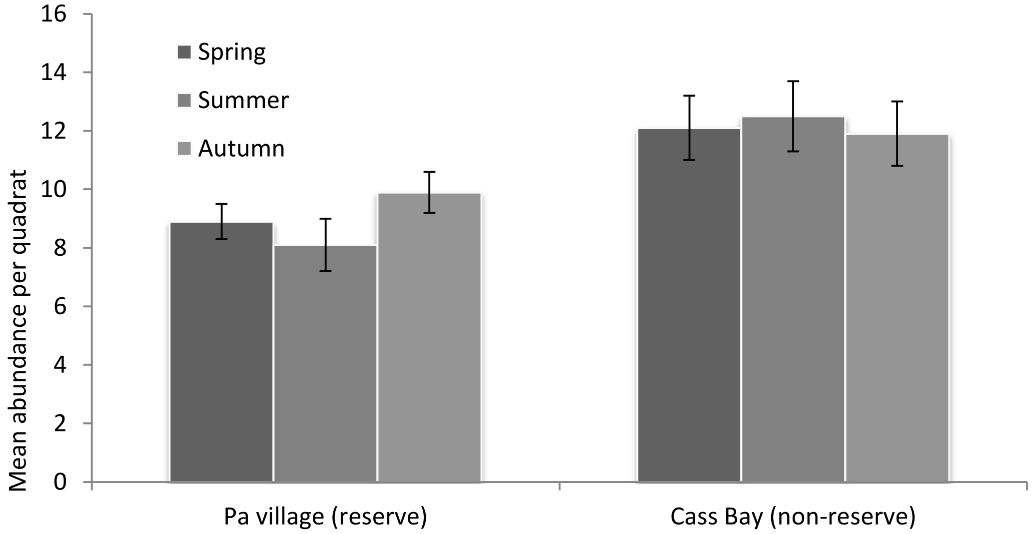


Figure B 2.1: Cockle mean abundance per quadrat (± s.e) collected at Pa village (reserve) spring n=89, summer n=81, autumn n=80 and Cass Bay (non-reserve) spring n=112, summer n=116, autumn n=119 during the preliminary surveys in spring October 2011, summer January 2011, and autumn April 2011

Table B 2.1: Result of 1 way ANOVA for Cockle average abundance per quadrat between reserve and non-reserve sites. At site 1: Pa village (reserve) and Cass Bay (non-reserve) during the preliminary surveys in spring October 2010, summer December 2010, and autumn April 2011

Source of variation	df	MS	F	P	significance
Sites					
Pa village & Cass Bay (spring)	1	51.2	8.88	0.008	S
Error	18	5.77			
Pa village & Cass Bay (summer)	1	96.8	11.5	0.003	S
Error	18	8.41			
Pa village & Cass Bay (autumn)	1	20.0	2.65	0.120	NS
Error	18	7.54			

Table B 2.2: Result of 1 way ANOVA for Cockle seasonal average abundance per quadrat within reserve and non-reserve sites. At site 1: Pa vilage (reserve) and Cass Bay (non-reserve)during the preliminary surveys in spring October 2010, summer December 2010, and autumn April 2011. Sp=spring sum=summer and aut=autumn

Source of variation	df	MS	F	P	significance
Season					
Pa village reserve (sp, sum & aut)		8.13	1.63	0.214	NS
Error		4.99			
Cass Bay non-reserve (sp, sum, aut)		0.93	0. 09	0.906	NS
Error		9.49			

2.2 Shell Lengths

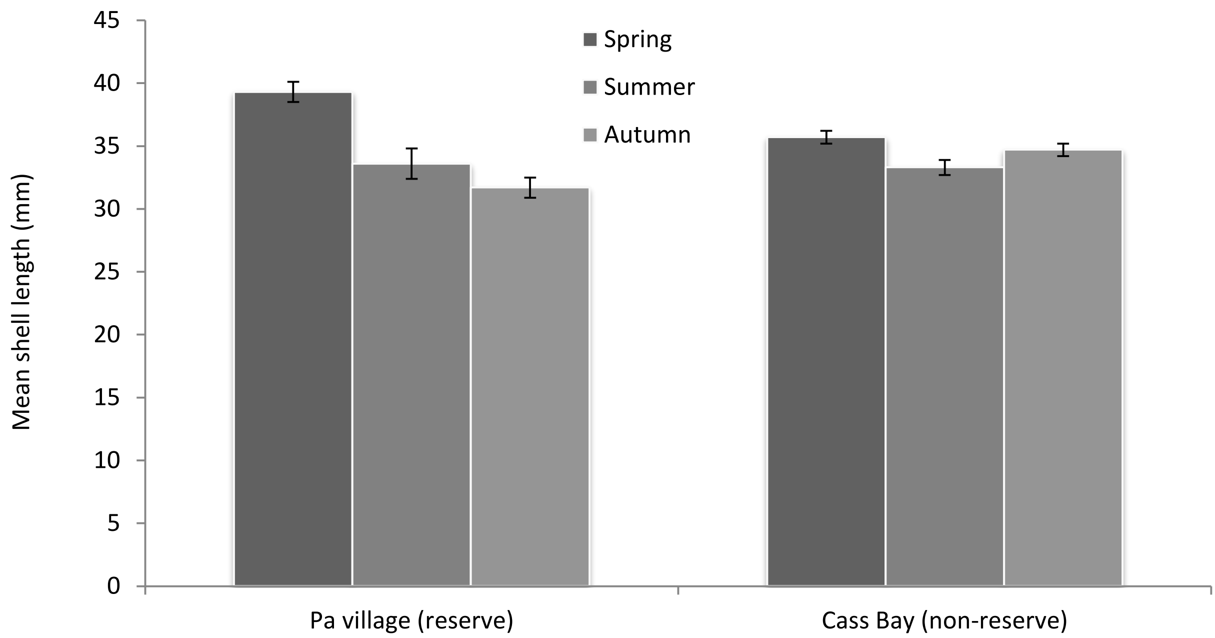


Figure B 2.2: Cockle mean shell length (± s.e) collected from Pa village(reserve) and Cass Bay (non-reserve) during the preliminary surveys in spring October 2011, summer January 2011, and autumn April 2011

Table B 2.3: Result of 1way ANOVA for cockle mean shell lengths at the Pa viilage reserve and non-reserve site at Cass Bay during the preliminary surveys in spring October 2011, summer January 2011, and autumn April 201

Source of variation	df	MS	F	P	significance
Sites					
Pa village & Cass Bay (spring)	1	641.81	10.37	0.001	S
Error	208	61.84			
Pa village & Cass Bay (summer)	1	7.37	0.08	0.77	NS
Error	204	89.23			
Pa village & Cass Bay (autumn)	1	1178.02	14.8	0.001	S
Error	215	79.49			

Table B 2.4: Result of 1 way ANOVA for cockle seasonal mean shell length within Pa village reserve and Cass Bay non-reserve site during the preliminary surveys in spring October 2010, summer December 2010, and autumn April 2011. Sp=spring sum=summer and aut=autumn

Source of variation	df	MS	F	P	significance
Season					
Pa village (sp, sum, & aut)	2	2022.13	23.06	0.001	S
Error	267	87.67			
Cass Bay (sp, sum, & autumn)	2	189.62	2.75	0.06	NS
Error	362	68.85			

2.3 Size structure

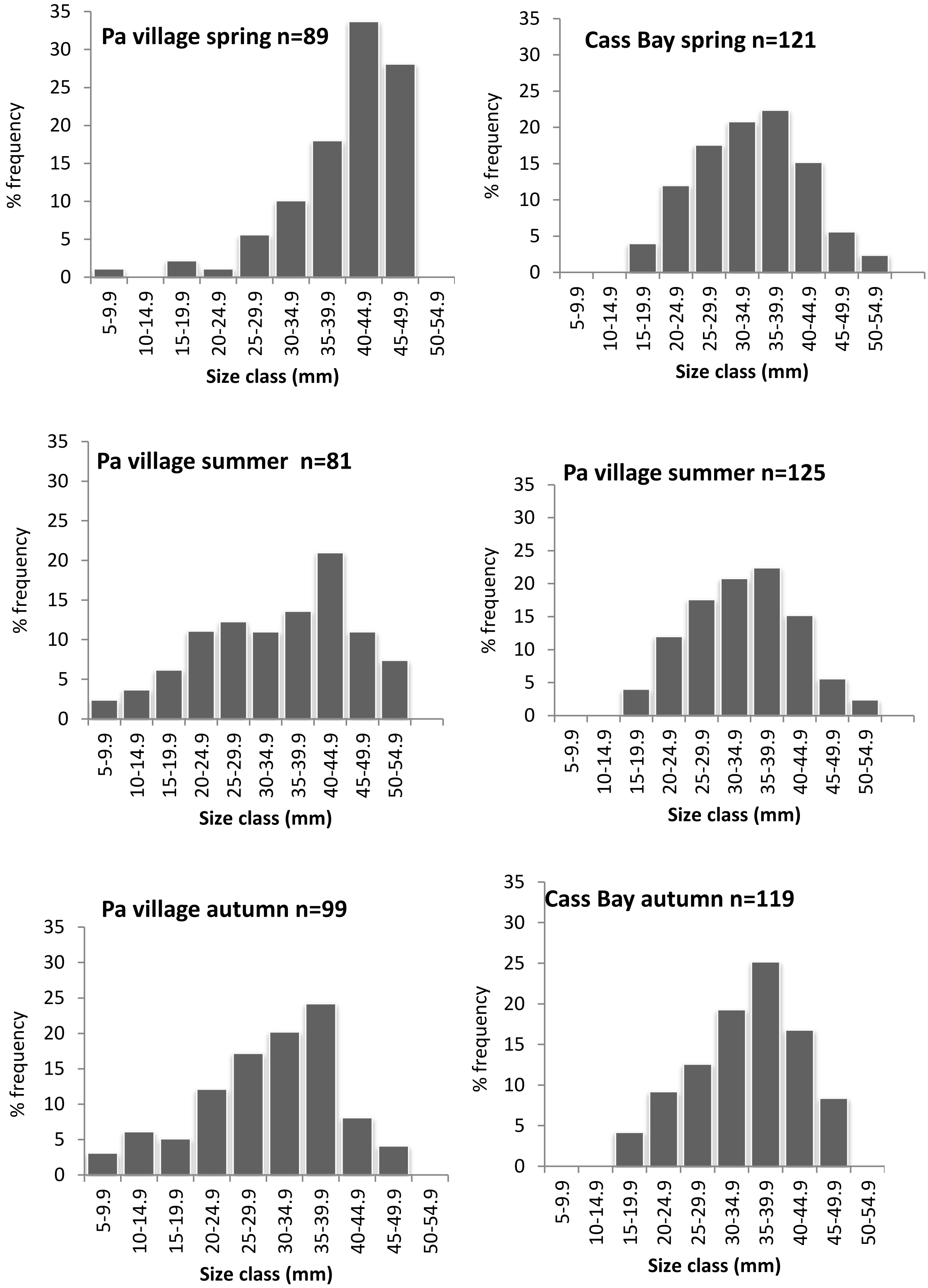


Figure B 2.3: Size frequencies of cockles at Pa village (reserve) and Cass Bay (non-reserve) during the preliminary survey.

Appendix 3: Turbo Preliminary Survey Results

3.1 Abundance and density

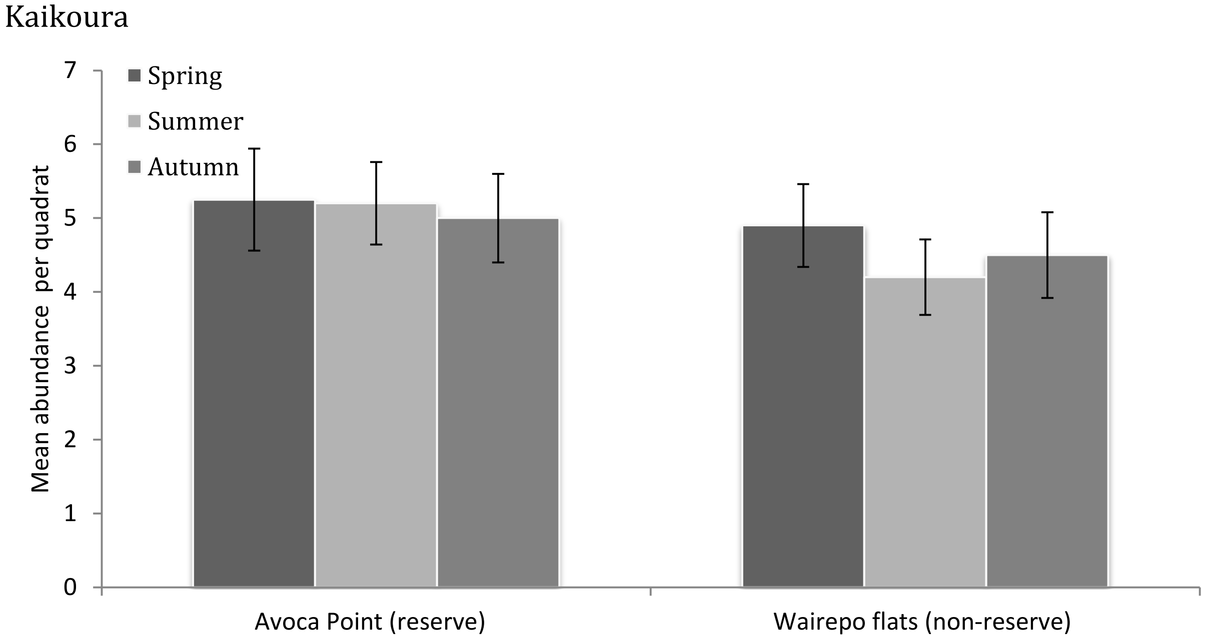


Figure C. 3.1: *Turbo smaragdus* mean abundance per quadrat (± s.e) collected at Avoca Point (reserve) spring n=105, summer n=104, autumn n=99 and Wairepo flats (non-reserve) spring n=98, summer n=84, autumn n=90 during the preliminary surveys in spring October 2011, summer January 2011, and autumn April 2011.

Table C **3.1: Result of 1 way ANOVA for *Turbo* average abundance per quadrat between Avoca Point (reserve) and Wairepo flats (non-reserve) during the preliminary surveys in spring October 2010, summer December 2010, and autumn April 2011**

Source of variation	**df**	**MS**	**F**	**P**	**significance**
Sites					
Avoca Point & Wairepo flats (spring)	1	1.2	0.15	0.698	NS
Error	38	8.0			
Avoca Point & Wairepo flats (summer)	1	10.0	1.84	0.183	NS
Error	38	5.4			
Avoca Point & Wairepo flats (autumn)	1	2.0	0.29	0.597	NS
Error	38	7.1			

Table C 3.2: Result of 1 way ANOVA for *Turbo* comparing seasonal average abundance per quadrat at Avoca Point (reserve) and Wairepo flats(non-reserve) during the preliminary surveys in spring October 2010, summer December 2010, and autumn April 2011. Sp=spring sum=summer and aut=autumn

Source of variation	**df**	**MS**	**F**	**P**	**significance**
Season					
Avoca Point reserve (sp, sum & aut)	2	0.52	0.07	0.933	NS
Error	59	7.47			
Wairepo flats non-reserve (sp, sum, aut)	2	2.47	0.40	0.671	NS
Error	59	6.14			

3.2 Banks Peninsula

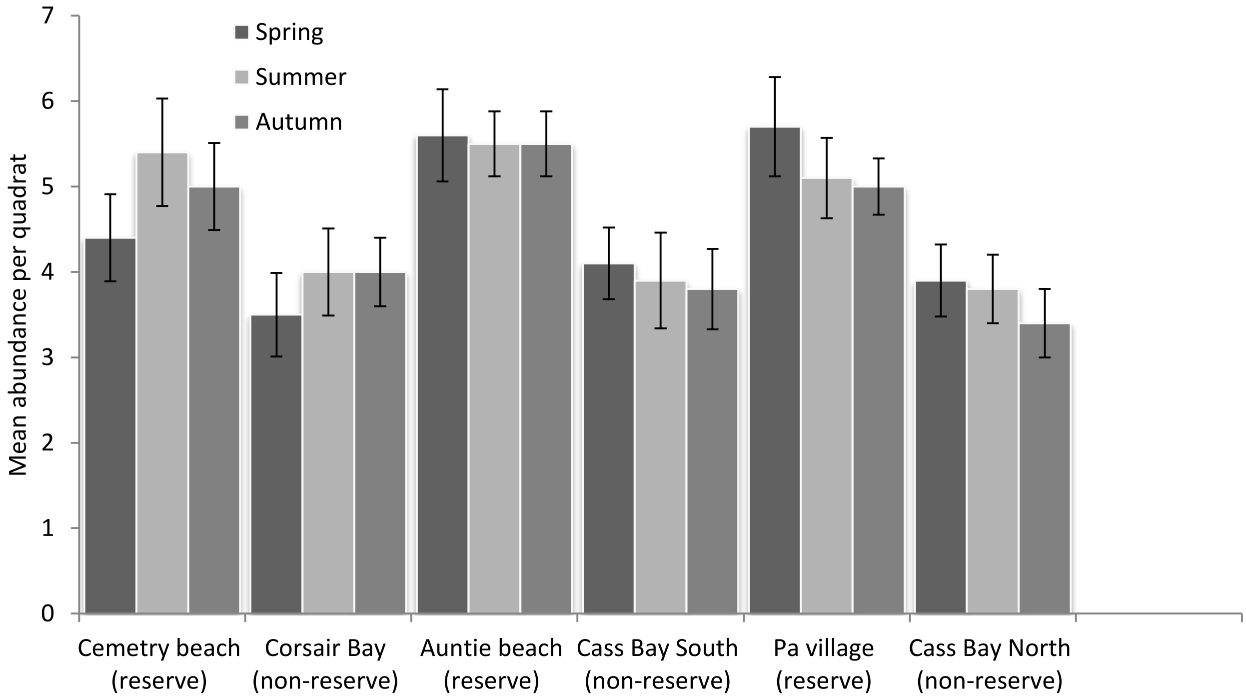


Figure C 3.2: *Turbo smaragdus* mean abundance per quadrat (± s.e) collected from site 1: Cemetry beach spring n=88, summer n=107, autumn n=100 and Corsair Bay spring n=69, summer n=80, autumn n=79. Site 2: Auntie beach spring n=112, summer n=110, autumn n=110 and Cass Bay South spring n=81, summer n=78, autumn n=76. Site 3: Pa village spring n=102, summer n=113, autumn n=100 and Cass Bay North spring n=77, summer n=75, autumn n=68 during the preliminary surveys in spring October 2010, summer December 2010, and autumn April 2011

Table C 3.3: Result of 1 way ANOVA for *Turbo* comparing average abundance per quadrat between reserve and non-reserve sites. Pair 1: Cemetery beach (reserve) and Corsair Bay (non-reserve) and Pair 2: Auntie beach (reserve) and Cass Bay South (non-reserve) and Pair 3: Pa village (reserve) and Cass Bay North during the preliminary surveys in spring October 2010, summer December 2010, and autumn April 2011

Source of variation	df	MS	F	P	significance
Pair 1					
Cemetery beach & Corsair Bay (spring)	1	9.0	1.85	0.182	NS
Error	38	5.0			
Cemetery beach & Corsair Bay (summer)	1	18.2	2.74	0.106	NS
Error	38	6.7			
Cemetery beach & Corsair Bay (autumn)	1	11.0	2.45	0.126	NS
Error	38	4.5			
Pair 2					
Aunties beach & Cass Bay South (spring)	1	24.0	5.02	0.031	S
Error	38	4.8			
Auntie beach & Cass Bay South (summer)	1	32.4	6.87	0.013	S
Error	38				
Auntie beach & Cass Bay South (autumn)	1	28.90	7.72	0.008	S
Error	38	3.74			
Pair 3					
Pa village & Cass Bay North (spring)	1	32.4	6.25	0.017	S
Error	38	5.19			
Pa village & Cass Bay North (summer)	1	18.22	4.69	0.037	S
Error	38	3.88			
Pa village & Cass Bay North (autumn)	1	25.60	9.46	0.004	S
Error	38	2.71			

Table C 3.4: Result of 1 way ANOVA for *Turbo* seasonal average abundance within reserve and non-reserve sites for the preliminary surveys in spring October 2010, summer December 2010, and autumn April 2011. Sp=spring sum=summer and aut=autumn

Source of variation	df	MS	F	P	significance
Season					
Cemetery beach reserve (sp, sum, & aut)	2	4.62	0.74	0.481	NS
Error	59	6.23			
Corsair Bay non-reserve (sp, sum, & aut)	2	1.85	0.42	0.662	NS
Error	59	4.45			
Aunties beach reserve (sp, sum, & aut)	2	0.87	0.22	0.807	NS
Error	59	4.42			
Cass Bay South non-reserve (sp, sum, & aut)	2	0.32	0.07	0.935	NS
Error	59	4.74			
Pa village reserve (sp, sum, & aut)	2	2.45	0.54	0.588	NS
Error	59	4.57			
Cass Bay North non-reserve (sp, sum, & aut)	2	1.12	0.34	0.713	NS
Error	59	3.28			

3.3 Shell lengths: Kaikoura reserve

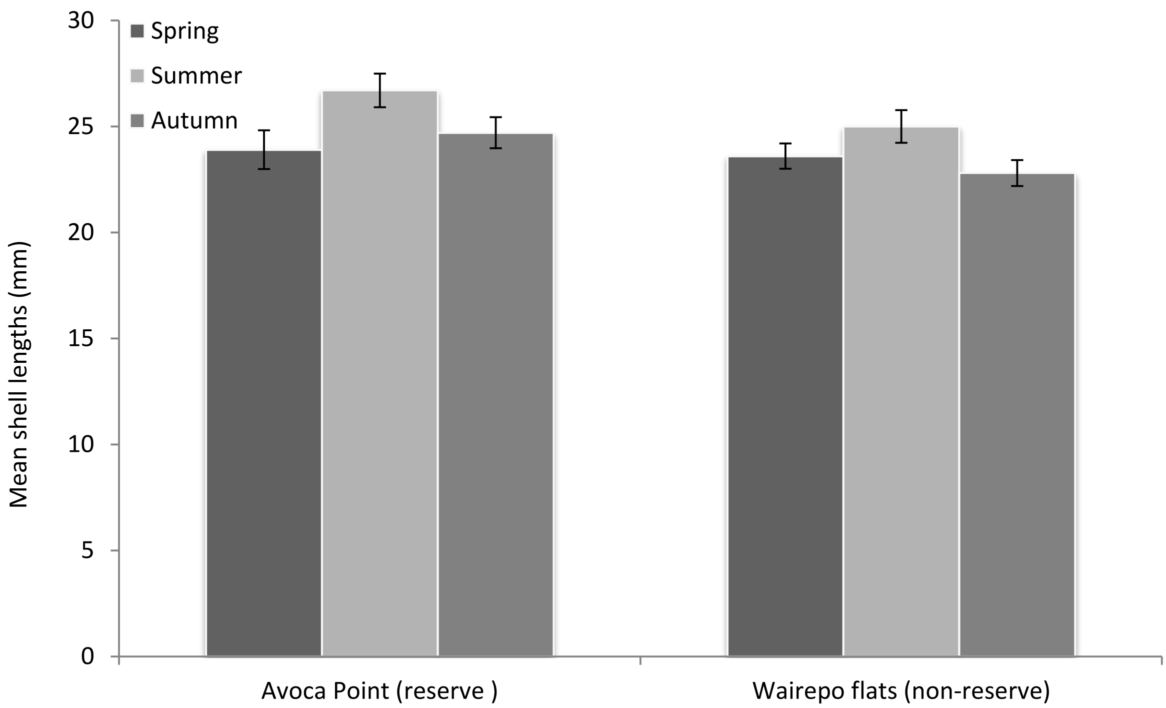


Figure C. 3.3: *Turbo smagradus* mean shell length (± s.e) collected from Avoca Point (reserve) and Wairepo flats (non-reserve) during the preliminary surveys in spring October 2011, summer January 2011, and autumn April 201

Table C 3.5: Result of 1way ANOVA for *Turbo* mean shell lengths at the Avoca Point reserve and non-reserve site at Wairepo flats during the preliminary surveys in spring October 2011, summer January 2011, and autumn April 2011

Source of variation	**df**	**MS**	**F**	**P**	**significance**
Sites					
Avoca Point & Wairepo flats (spring)	1	7.0	0.11	0.736	NS
Error	201	61.3			
Avoca Point & Wairepo flats (summer)	1	121.3	2.05	0.154	NS
Error	186	59.2			
Avoca Point & Wairepo flats (autumn)	1	171.5	3.90	0.050	S
Error	187	44.0			

Table C 3.6: Result of 1 way ANOVA for *Turbo* seasonal mean shell length within reserve and non-reserve sites. Avoca Point (reserve) and Wairepo flats(non-reserve) during the preliminary surveys in spring October 2010, summer December 2010, and autumn April 2011. Sp=spring sum=summer and aut=autumn

Source of variation	**df**	**MS**	**F**	**P**	**significance**
Season					
Avoca Point reserve (sp, sum, & aut)	2	206.2	3.00	0.051	S
Error	305	68.8			
Wairepo flats non-reserve (sp, sum, & autumn)	2	113.9	2.88	0.058	S
Error	269	39.3			

Banks Peninsula

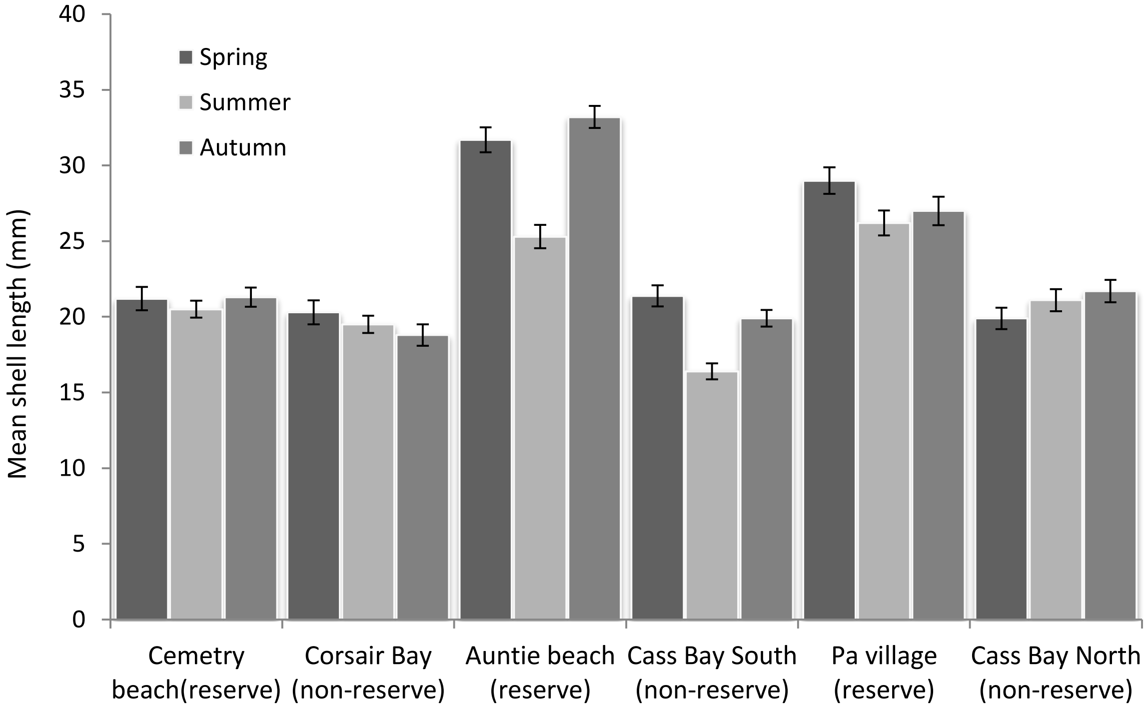


Figure C 3.4: *Turbo smagradus* mean shell length (± s.e) collected from Pair 1:Cemetery beach (reserve) and Corsair Bay (non-reserve site). Pair 2: Aunties beach (reserve) and Cass Bay South (non-reserve). Pair 3: Pa village and Cass Bay North during the preliminary surveys in spring October 2010, summer December 2010, and autumn April 2011

Table C 3.5: Result of 1 way ANOVA for *Turbo comparing the* mean shell length within reserve and non-reserve sites. Pair 1: Cemetery beach (reserve) and Corsair Bay (non-reserve). Pair 2: Aunties beach (reserve) and Cass Bay South (non-reserve). Pair 3: Pa village (reserve) and Cass Bay North during the preliminary surveys in spring October 2010, summer December 2010, and autumn April 2011

Source of variation	df	MS	F	P	significance
Pair 1					
Cemetery beach & Corsair Bay (spring)	1	26.9	0.56	0.457	NS
Error	155	48.3			
Cemetery beach & Corsair Bay (summer)	1	43.1	1.42	0.234	NS
Error	185	30.3			
Cemetery beach & Corsair Bay (autumn)	1	262.2	6.39	0.012	S
Error	177	41.0			
Pair 2					
Aunties beach & Cass Bay South (spring)	1	5000.1	81.77	0.001	S
Error	191	61.1			
Auntie beach & Cass Bay South (summer)	1	3598	75.38	0.001	S
Error	186	47.7			
Auntie beach & Cass Bay South (autumn)	1	8064	181.2	0.001	S
Error	185	44.5			
Pair 3					
Pa village & Cass Bay North (spring)	1	3683.9	64.68	0.001	S
Error	177	57			
Pa village & Cass Bay North (summer)	1	1154.9	17.04	0.001	S
Error	186	67.8			
Pa village & Cass Bay North (autumn)	1	1140.8	16.96	0.001	S
Error	166				

Table C 3.6: Result of 1 way ANOVA for *Turbo* comparing seasonal mean shell length within reserve and non-reserve sites for the preliminary surveys in spring October 2010, summer December 2010, and autumn April 2011. Sp=spring sum=summer and aut=autumn

Source of variation	**df**	**MS**	**F**	**P**	**significance**
Season					
Cemetery beach reserve (sp, sum, aut)	2	16.4	0.40	0.673	NS
Error	292	41.4			
Corsair Bay non-reserve (sp, sum, aut)	2	42.9	1.17	0.313	NS
Error	225	36.8			
Aunties beach reserve (sp, sum, aut)	2	1971.2	29.34	0.001	S
Error	330	67.2			
Cass Bay South non-reserve (sp, sum, aut)	2	518.3	81.17	0.001	S
Error	232	28.5			
Pa village reserve (sp, sum, aut)	2	240.7	2.96	0.053	S
Error	312	81.4			
Cass Bay North non-reserve (sp, sum, aut)	2	58.7	1.51	0.224	NS
Error	217	38.9			

3.4 Adult and Juveniles

Kaikoura

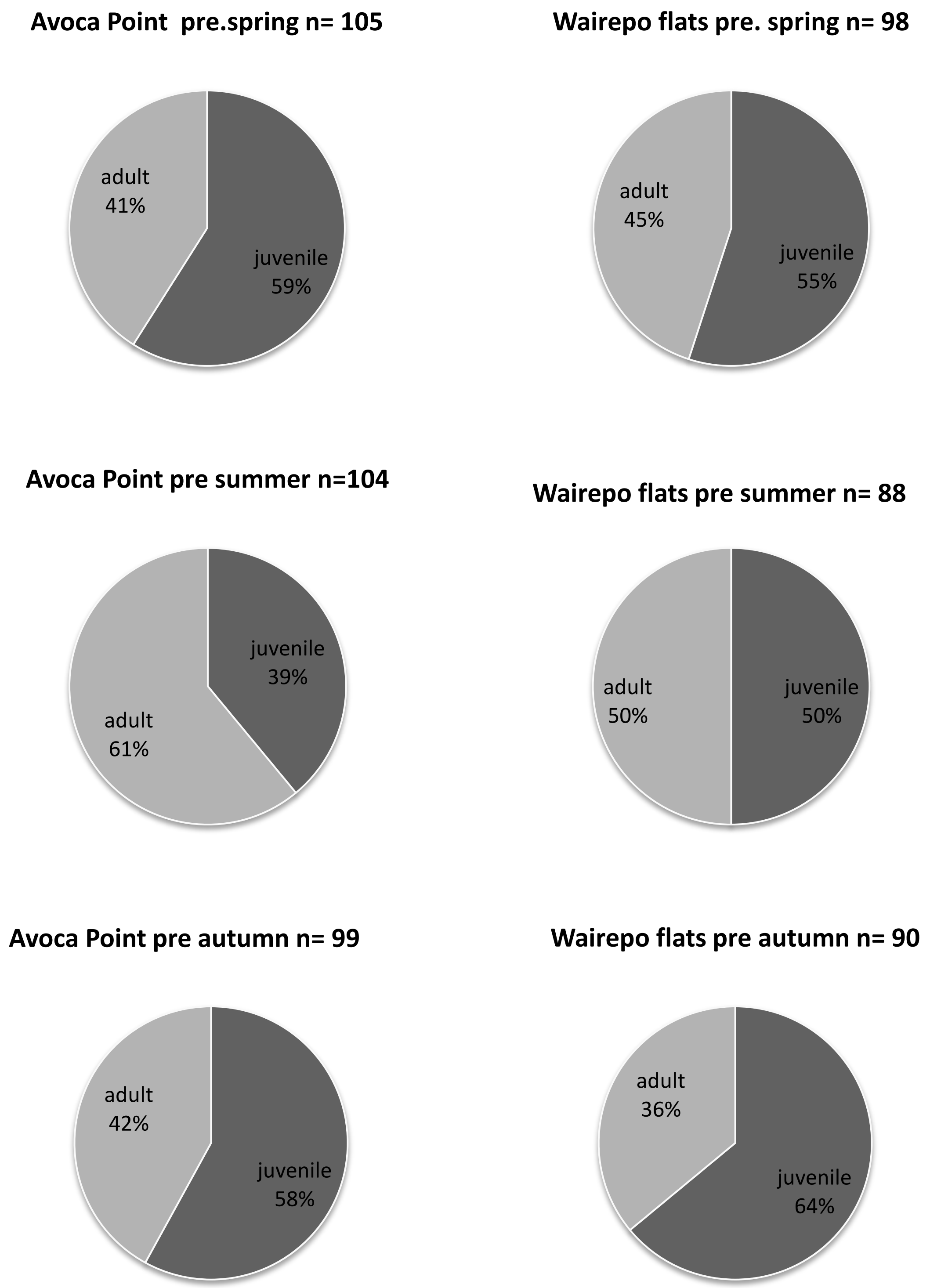


Figure C 3.5: Percentage of juvenile (< 25 mm) and adult (> 25 mm) of Turbo population at Avoca Point (reserve) and non-reserve site at Wairepo flats during the preliminary survey spring October 2010, summer December 2010and autumn April 2011.

Banks Peninsula

Comparison 1: Cemetery Breach (reserve) and Corsair Bay (non-reserve)

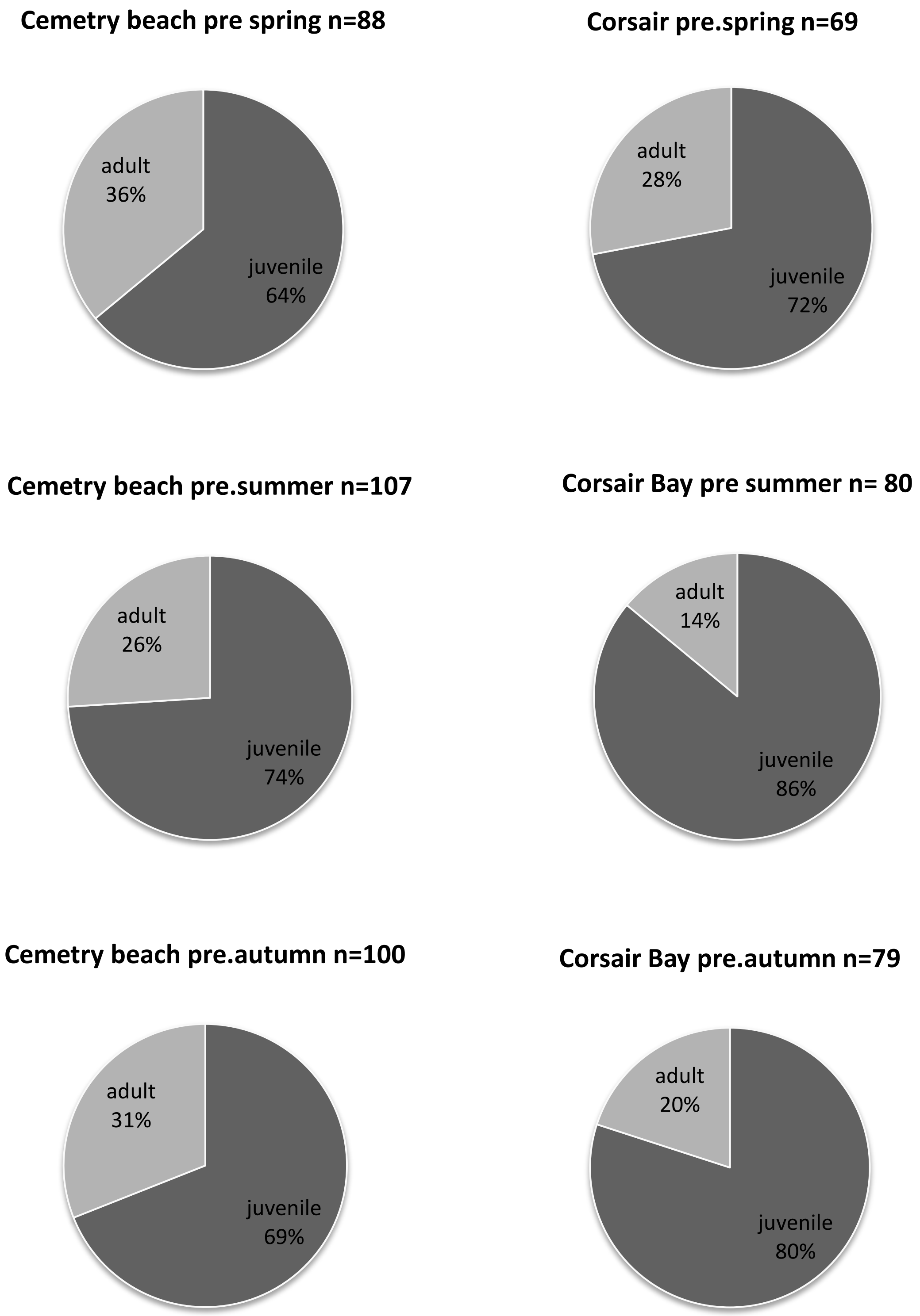


Figure C 3.6. Percentage of juvenile (< 25 mm) and adult (> 25 mm) of *Turbo* population at site 1: Cemetery beach (reserve) and non-reserve site at Corsair Bay during the preliminary survey spring October 2010, summer December 2010 and autumn April 2011.

Comparison 2: Aunties beach (reserve) and Cass Bay South (non-reserve)

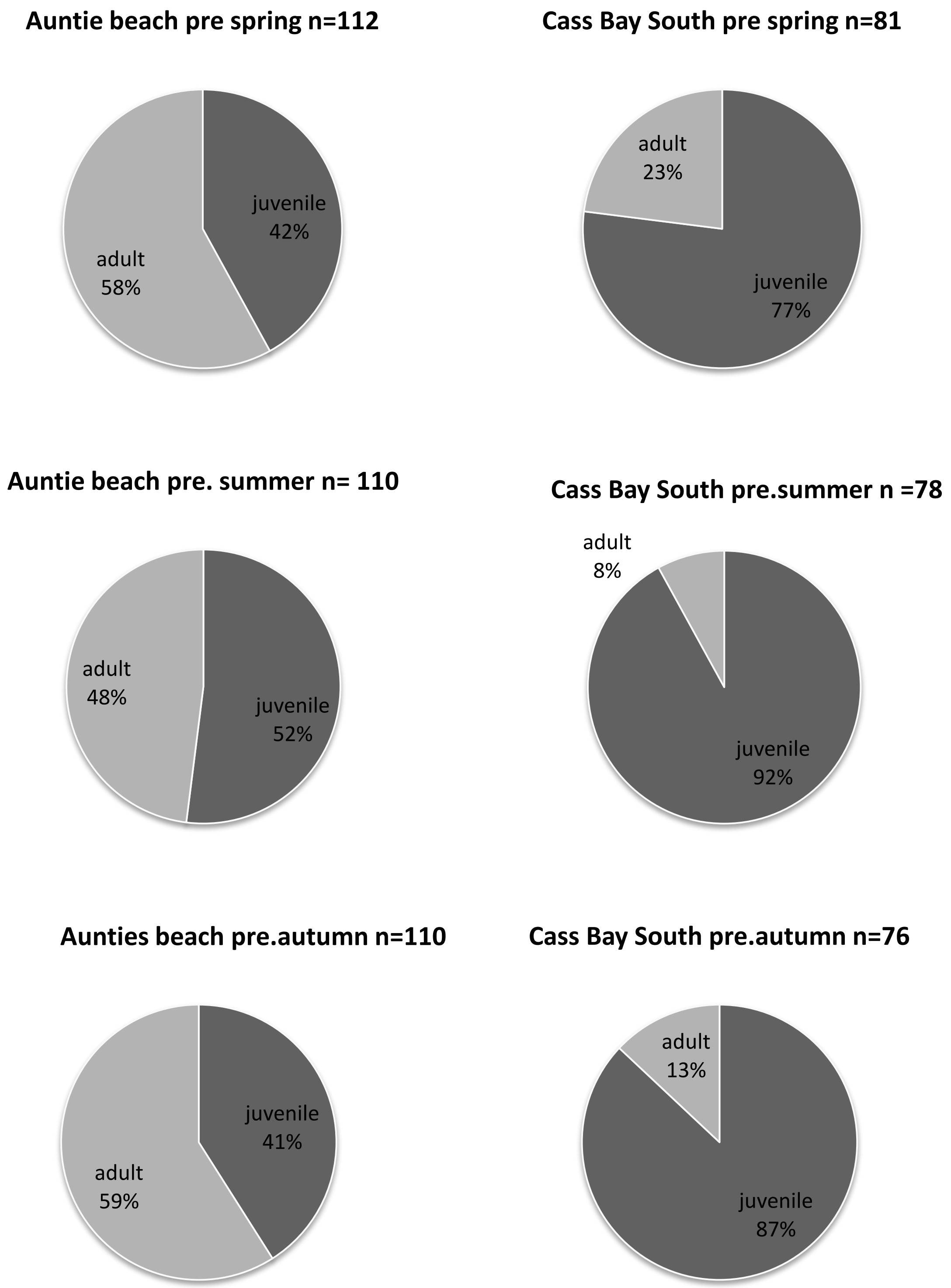


Figure C 3.7: Percentage of juvenile (< 25 mm) and adult (> 25 mm) of Turbo population at site 2 Aunties beach (reserve) and non-reserve site at Cass Bay South during the preliminary survey spring October 2010, summer December 2010and autumn April 2011

Port Levy: Koukourarata Mataitai reserve

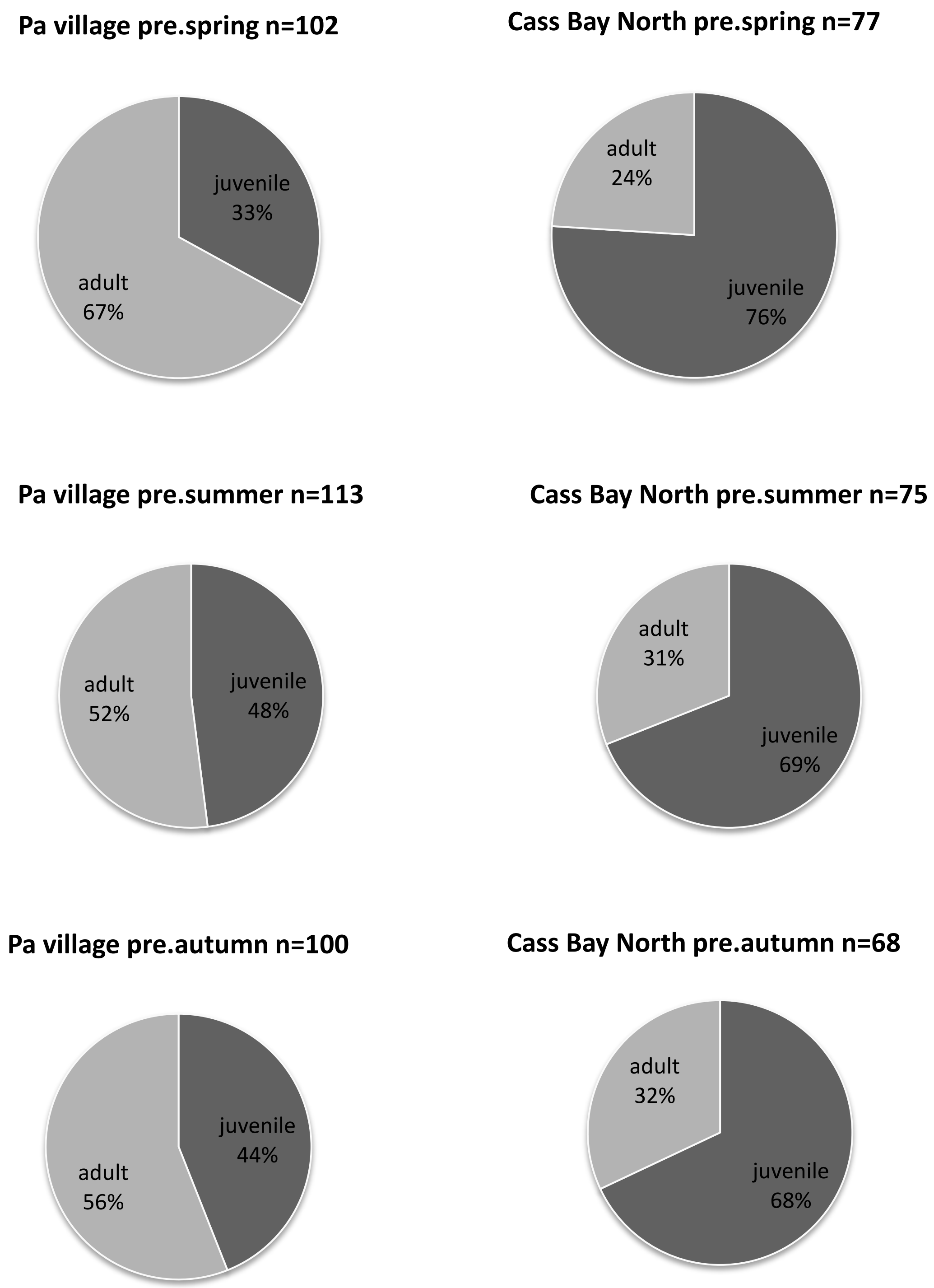


Figure C 3.8: Percentage of juvenile (< 25 mm) and adult (> 25 mm) of *Turbo* population at site Pa village (reserve) and non-reserve site at Cass Bay North during the preliminary survey spring October 2010, summer December 2010and autumn April 201